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THE VARIETIES OF HERRING

by Friedrich HEINCKE

of Oldenburg

PART TWO

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Foreword

It is not without some apprehension that I am presenting to the public this continuation of my investigations on herring[1]. I have boldly gone my own way, outside of the great zoological laboratories where the most wonderful products of human endeavor and acumen are elaborated every day with knife and microscope, far from the trodden path, armed only with compass and ruler. Instead of an array of finely executed drawings, the reader will find here an almost stifling abundance of numbers and symbols, and may be shocked if I expect him to translate all of them, without exception, into words. Are they really going to advance our knowledge? Or are they only the worthless, inconclusive results of an amateur's play? I often asked myself these questions, as I pored over my numerous tables again and again, and combined and rearranged them in all kinds of ways. Although the work was not difficult, it was tedious, so far as that is possible for scientific work. But the Commission had moved to raise the question of the herring varieties; I had undertaken, as far as possible, to resolve it, and it seemed to me that the way which I had chosen was the only right one.

---

[1] Part One of these investigations, 'The Varieties of Herring, by Dr. Friedrich HEINCKE, Lecturer in Zoology at the University of Kiel', was published in Annual Reports 4, 5, and 6 of the Commission (1878) p. 37-132.

The result is better than I myself expected. Whoever takes the effort to follow my exposition will realize that the fruits of this study will be useful not only for those with a special interest in the question of herring varieties, but also for systematists and for Darwinians. Perhaps this study will help a little to reconcile these last two groups, which still have frequent and vigorous conflicts, and to persuade them that they can, and should, learn from each other. To build new knowledge on an old foundation-- that has been my goal.

Oldenburg, January 1881. The Author.

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Introduction

1. Method of the investigation

The method which I have employed in my investigations on herring is so peculiar and unusual that the reader must first be acquainted with it.

As already explained in Part One of my investigations, the question whether there are constant varieties of herring can be resolved only by examining, and describing with extreme precision, a very large number of individuals. All previous research on this subject has been completely inadequate, not because the authors lacked diligence and intelligence, but because their method of description did not suffice for recognition of the fine differences between races.

My new method is based on two principles.

1. Every individual should be described so clearly that misinterpretations are impossible, and so precisely that the most minute details can be recognized.

I achieve this goal by limiting myself to the external shape of the body, measuring linear dimensions and counting organs which repeat in series. In Part One of my investigations, I determined only the total length of each herring, the location of the dorsal fin, the ventrals, and the anus, the length of the anal fin, the maximal height of the body, the lateral head length, and the number of keel scales between the ventrals and the anus. In the present, second part, I have examined not only more individuals of every age class (at least 2000), but also a greater number of characters, viz., twelve to fourteen. These are: total length; location of the dorsal and ventral fins, and of the anus; lateral head length; height at the back of the head, maximal height, and height at the beginning of the caudal fin; length of the anal and dorsal fins; the number of keel scales between the head and the ventral fins, and between the ventrals and the anus; the total number of keel scales, the number of anal and ventral fin rays, and the number of vertebrae; sex, and maturation stage of sex products; and fat content.

Since it is not the absolute, but the relative size of a character that is useful for discerning individual traits, all measurements are expressed in relation to one, viz., the total length, defined as the distance from the tip of the lower jaw with the mouth closed to the midpoint of a straight line connecting the ends of the caudal fin, extended to the closest possible approximation of its natural position. Since both caudal lobes are not of equal length, this line perpendicular to the body axis will pass through the lower lobe somewhat before its distal end (see the explanatory illustration at the end of the text). I either take the measurement which is to be related to the total length (e.g., the lateral head length) as = 1; then the total length itself is expressed by a larger number such as 4.5 or 5.5-- i.e., the total length equals 4.5 or 5.5 times the head length. Or else, I take the total length as = 1000, and then the measurement (e.g., the length of the anal fin) is expressed by a lesser number, e.g., 80 or 100-- i.e., the length of the anal fin is 80/ 1000 or 100/ 1000 of the total length.

2. The description of each individual should be so brief and easy to read that hundreds of individuals can be compared simultaneously.

I achieve this by expressing the descriptions not in words, but through a formula composed of letters and numbers, in the following manner:

First I determine the range of variation for each character in a large number of herring. For example, the distance from the tip of the lower jaw with the mouth closed to the origin of the dorsal fin; if this measurement is taken as =1, in approximately 120 herring we find a range of variation from 2.08 to 2.37-- i.e., the distance to the dorsal fin is 1/ 2.08 to 1/ 2.37 times total length. I now divide this range of variation into three equal parts, designated 1, 2, and 3, as follows:

1. 2.08-2.17
2. 2.18-2.27
3. 2.28-2.37

If examination of more individuals yields values less than 2.08 or greater than 2.37, any number of equal-sized levels of variation can be added below or above the first three levels. Those below are designated 0, -1, -2, those above 4, 5, etc.

The use of these levels of variation has another advantage: small errors of measurement are eliminated. In most cases, I have attempted to estimate the mean error of measurement (caused by preserving the herring in alcohol, etc.) and I have chosen variation levels always wider than this error. Actually, a different series of codes and numbers should have been used for each measurement. However, for various reasons, I deliberately avoided this, and I do not believe that the reader will be inconvenienced.

I have also used variation levels when counting similar parts which repeat in series.

In this way, the description of fourteen characters is given by a formula of the following kind: 202.0-b-1-3aII-2bIIB-bIIß-56. 202.0 is the total length in millimeters. b is the variation level (index) of the lateral head length. 1 is the ratio of the length of the dorsal fin to the length of the anal. 3aII are the indices for body height at the three points where it was measured. 2bIIB is the formula for the location of the dorsal fin, the ventrals, and the anus, and the length of the anal fin. bIIß indicates the number of keel scales between the head and ventrals, between the ventrals and the anus, and the total number of keel scales. And 56 is the number of vertebrae.

With some practise, the description of a fish can be read from this formula almost as readily as if it were expressed in words. However, usually this is not even necessary. We can almost work with these formulae as a mathematician would work with mathematical formulae, translating only the final result into words. It is obvious that many aspects of the research could have been presented even more practically and conveniently, but the reader must grant that it is difficult to find the best technique when using an entirely new approach for the very first time.

In order to make it as easy as possible while studying this treatise to translate any given formula into words, an explanatory illustration with an explanation of all the symbols is provided at the end. Only those expressions which I use for the different ripeness stages of the sex products will be better explained here in the text.

Maturation stages of sex products

Stage	Ovaries	Testes
I.	Very narrow, pale yellowish red strands, often barely visible to the naked eye. Eggs visible only microscopically.	Very narrow, whitish strands, often barely visible. Recognizable as testes only under a microscope.

This stage occurs only in herring which have never spawned.

II.	Thicker strands, vinous in color, up to 100 mm in length and 4 mm thick. Eggs visible under a magnifying glass. Weight of both ovaries equals 1/ 100 to 1/ 40 of the body weight.	Thicker, reddish gray strands up to 100 mm in length, not grainy under a magnifying glass. Weight 1/ 100 to 1/ 40.
III.	Thicker, reddish-gray masses of distinct, flatly compressed eggs, up to 150 mm x 15 mm; with a magnifying glass, the germinal vesicles can be seen. Weight 1/ 40 to 1/ 10.	Thicker, reddish gray masses, over 100 mm long, filling the entire body cavity and injected with much blood. Seminal tubules visible with a magnifying glass. Weight 1/ 40 to 1/ 10.
IV.	Reddish yellow masses of very large eggs filling nearly the entire body cavity; some eggs are especially large and light. Weight 1/ 20 to 1/ 8.	Almost milky white masses filling, or almost filling, the entire body cavity. Under very strong pressure, a small, viscous drop of sperm emerges. Spermatozoa show sluggish movement. Weight 1/ 20 to 1/ 8.
V.	Large, light reddish yellow masses of many light eggs filling the entire body cavity. Under strong pressure, eggs emerge which are sticky, but do not yet have a complete capsule. Weight 1/ 10 to 1/ 4.	Pure milky white masses filling the entire body cavity. Even gentle pressure causes the emergence of a still viscous drop of sperm. Weight 1/ 10 to 1/ 4.
VI.	With the least pressure, fully ripe eggs emerge ready for fertilization.	With the gentlest pressure, abundant, rapidly dispersing sperm emerges. Spermatozoa show very lively movement.

VI.- VII.	Only partially spent. The occurrence of this stage is evidence that for individual herring, spawning takes days, if not weeks.	Same.
VII.	Completely spent; very shrivelled, reddish gray sacs with thick, folded walls and a few eggs left inside.	Same, with isolated residual sperm.

2. Purpose of the investigation

In Part One, using my new method, I was able to demonstrate two clearly differentiated races within the species Clupea harengus.[1] They differed in the relative location of the dorsal and ventral fins, the location of the anus, and the length of the anal fin. One group comprised individuals with formulae for these four characters such as 1aIA, 1bIA, 2aIB, 2aIIA, etc. (Figure 1); the other, those described by formulae such as 2bIIB, 2bIIIB, 3bIIIB, 3cIIIC, etc. (Figure 2). Individuals with 2aIIB or 1bIIIB are intermediate.

I designated these two groups as 'varieties', naming the first 'var. a' or 'North Sea herring' and the second 'var. b' or 'Baltic herring'. For, the investigations showed that both forms occurred together at all locations studied, but never in the same ratio. At Königsberg, for example, the ratio of a to b was 1: 5, in Kiel Bay 1: 2, in the Great Belt 2: 1, and in the North Sea itself (Peterhead, Scotland) b was so infrequent that the ratio exceeded 9: 1. Thus, while var. b was the dominant form in the Baltic, var. a was dominant in the North Sea. Incidentally, the differences observed were found to be completely independent of age and sex.

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[1] p. 105 ff. [German text]

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Further investigations, mainly by Dr. H. A. MEYER[1], concerning the spawning time of herring in the western Baltic soon led to the hypothesis that var. b, which constituted the majority in this area, are spring spawners in the brackish water of the Schlei, whereas the less numerous var. a are autumn spawners in salt water.

This hypothesis was strengthened by my observations[2] on the remarkable transparent, almost eel-like juveniles of herring. For, two different types of larvae can be differentiated. One type (Figure 5) has a thickset body with the dorsal fin and the anus relatively far forward, and attains the definitive herring form already with a total length of 38 to 45 mm. The other type (Figure 4) is much more slender, with the dorsal fin and anus farther back, and it does not attain a complete set of scales and take on the definitive form until it has a length of 50 to 60 mm. These two types also occur at different times and in different places in the western Baltic. For, the long, slender larvae appear in large numbers in salt water near the coast from January to May, chiefly in April. Whereas the short, thickset type are found only in the brackish water of the Schlei up to Schleswig from May to July, mainly in June.

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[1] Annual reports IV, V, and VI of the Commission, p. 229 ff.

[2] loc. cit. p. 97 ff.

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It seemed reasonable to identify the small type of larvae in the Schlei as the offspring of the brackish-water spring spawners (i.e., var. b), and the large ocean type as the offspring of the salt-water autumn spawners (var. a). Already in Part One, I ventured to hypothesize[1] that the differences between the two larval types in the location of fins, anus, etc. would actually develop into the differentiating characters of varieties a and b at the time when the definitive herring form was assumed. Since, in addition to this, the experiments of Dr. MEYER demonstrated that temperatures have a considerable influence on the duration of embryonic development in herring, and the two types of larvae are born in different seasons and at different places-- and therefore under quite different physical conditions, we may finally conjecture that differences in environmental conditions during the larval stage gave rise to the two varieties.

The major goal of the present study is to resolve this difficult, but interesting question. However, such an undertaking requires a deeper and broader base than was provided by my previous investigations. More individuals and characters would have to be investigated, and herring from other seas would have to be compared; but most especially, we should trace every detail of the life, spawning time, and growth of the herring in Kiel Bay.

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[1] l.c., p. 100.

The specific questions which I posed, and which are largely answered in the following pages, are as follows:

I. What is the situation in Kiel Bay and in the neighboring parts of the Baltic?

a. Are the spring and autumn herring found in Kiel Bay identical with var. a and var. b?

b. Are there other differences between the two races in other characters, apart from those already discovered?

c. Can we differentiate both races in every size class from larvae to the largest sexually mature fish? Does each variety have a separate course of development, or can one change into the other?

d. What are the causes and general nature of the varietal differences?

e. Does an individual herring actually spawn only once a year? How long is the interval from the emptying of the gonads to the next spawning? How long is the spawning season of each race?

f. Are herring migrations dependent on any specific factors?

A seventh question-- How fast do the animals grow, particularly in the period directly after hatching, and is there a difference between the two races in this regard?-- can be fully resolved only by experiments. Dr. MEYER has undertaken this investigation.

II. Can races with different habits and ways of life be established also outside of Kiel Bay?

III. Continued comparison of herring and sprat: Are there varieties of Sprat, as well?

Chapter One

The herring of Kiel Bay

The most important arguments presented on the following pages are based on more than 700 herring of both varieties (a and b) listed in Table I, all from Kiel, Eckernförde, or the Schlei. Using this table, the reader will be able to verify each of my conclusions. At the same time, he will have at his disposal a collection of material of a kind not furnished anywhere else in our zoological literature. This material is very suitable for studying the variability of species in relation to individual development, sex, and life cycle. Hence, this table will be useful even to readers not concerned specifically with herring or with ichthyology.

In a study to be published later on 'individual variation and speciation', I shall have an opportunity to utilize this table much more broadly than I can here without deviating too far from the actual purpose of the present research. As regards the arrangement of the table, it is particularly important for the resolution of the questions posed in this investigation. I must admit that it is mainly thanks to the table that these questions could be resolved accurately. Once the table was complete, I could simply read the secret of the herring races, their spawning times, the duration of the maturation of the sex products, etc., from the table. It contains almost a complete history of the Kiel herring, which need only be translated into verbal language to be recognized at once.

The table runs in two parallel divisions on opposite pages. All individuals of var. a are on the left, and all those of var. b are on the right. Within each division, individuals are listed in order of increasing size from 20 mm to 320 mm, so that individuals of the same size, but different races always appear together on left and right.

To save space, the printed version of the table is considerably abbreviated. The original layout left space at every millimeter for five individuals on each side, to accommodate up to 3000 specimens altogether. Although it was unlikely that so many specimens would ever be examined, this arrangement still offered considerable advantages: first, because in some size ranges (e.g., 225-240 mm) sufficient numbers actually were examined, and secondly, because each new specimen examined could be entered directly in the table without any difficulty. For some sizes, e.g., 100-140 mm, there were very wide gaps.

The columns are arranged differently in the first part of the table, comprising fish from 20 to 150 mm in length, than in the second part. In the second part, there are additional columns showing the sex of the specimen, the maturation stage of the genital products, and the number of vertebrae, so that there are twelve columns altogether. Column 1 shows the absolute total length in millimeters;

column 2 the formula of the lateral head length; column 3 the ratio of the length of the anal fin to the length of the dorsal; column 4 the index of the three height measurements; column 5 the formula for the three basic characters, viz., location of the fins and anus and length of the anal fin; column 6 the indices for numbers of keel scales; columns 7 and 8 the date and location at which the fish was caught; columns 9 and 10 the sex of the fish, and the maturation stage of the sex products; column 11 the number of vertebrae; and column 12 contains other remarks, such as the level of the fat content, etc. This arrangement offers the following advantages:

1. The development of each varietal form can be seen by comparing gradually increasing sizes.

2. Individuals of the same race with equal or nearly equal size are listed consecutively, so that individual variations related to size can be directly recognized.

3. Individuals of the same race with equal size, but different sex or different ripeness stages are listed consecutively, so that differences of form related to sex or maturation stage are recognizable.

4. Individuals of different races, but the same size and sex are listed directly opposite each other, so that at every size, the differences between var. a and var. b can be recognized.

5. For each individual, the date when it was caught and the maturation stage of the sex products indicate whether it was an autumn spawner or a spring spawner.

6. Comparison of the date and location of the catch with the maturation stage reveals where the fish was when it attained a certain stage of ripeness. From these data, we can draw some inferences regarding the migratory behavior of herring, etc.

I. Sexually mature autumn and spring herring

The first question is whether the two different morphological varieties a and b are identical with the different behavioral types, viz., autumn spawners and spring spawners.

In order to resolve this, we must understand the precise meaning of these terms.

Those who have read Part One[1] will recall that with reference to combinations of four frequently mentioned characters, in addition to Group I or var. a and Group II or var. b, I differentiated a third group, comprising very rare combination formulae (such as 2aIC, 2cIIIC, etc.) sometimes occurring only in isolated individuals, and sometimes transitional towards Sprat. Numerically, this third group comprised no more than 25 % of any local form. I shall now dispense with this group, and divide its members between Groups I and II. In the table below, the formulae to the left of the line describe those fish of var. a which are most similar to var. b, and those on the right are the individuals of var. b which most resemble var. a.

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[1] loc. cit., p. 115, note.

	var. a.	*var. b.*	
	: : 1b IIIB	1c IIIB : :	
1a IA (Extreme)	: : 2a IIC	2a IIIC : :	3c IIIC (Extreme)
	: : 2b IA	2b IIA : :	
	: : 3a IIA	3a IIIA : :	

A look through the long table at the end of the text will provide sufficient orientation. I probably need not repeat that the line which I have drawn is to some extent arbitrary, and there is no distinct boundary between the two races. Readers who consider how gradual all transitions are in nature and how small-- albeit clearly recognizable-- are the morphological differences involved in this case, will take no offence.

The differentiation between autumn and spring spawners is more difficult than differentiating the morphological varieties. The fact that herring were found spawning in every month of the year (with the single possible exception of July) also demonstrates that these two forms are not sharply separated. However, it is equally certain that completely intermediate cases (i.e., fish spawning in January or July, or early in August) are infrequent.

Here, to draw the boundary as accurately as possible, we should first investigate whether individual herring spawn once or twice a year, and how long it takes for the genital products to mature in the body of the fish. For various reasons which will become clear later, I shall take the liberty of anticipating the results of this investigation for the present, and postponing the proof to Chapter 5. The reader can take it as certain that with very minor exceptions, herring spawn only once a year; the spawning period of each race is about 2½ months, and the remaining time-- viz., 9½ months-- is used to ripen new sex products. However, it should be noted that in the first two or three months after emptying the gonads, a spent and emaciated herring must first consume sufficient food for its recovery; hence the formation of new eggs or spermatozoa will not become detectable until after this, so that their maturation then takes seven or eight months.

It should also be kept in mind that the situation of the autumn spawners in Kiel Bay is slightly different from that of the autumn spawners in the Great Belt. For, so far, Dr. MEYER and I have found herring spawning in Kiel Bay only from the end of October to the beginning of January, so that it seems as if the Kiel herring spawn later than the Korsör herring. However, together with the fully ripe individuals caught at this time, there are others which have evidently spawned recently, and still others in which the condition of the gonads is such that we must conclude that they would not spawn until the end of January, or even February. They, too, should be classed as autumn or winter spawners.

The spawning situation of the spring herring is much clearer, because their numbers are larger and their main spawning area, the Schlei, is more accessible for research than the open sea. Almost all herring caught in the Schlei from the middle of March to early June are newly spent, fully ripe, or nearly ripe; only those which feel the drive to spawn seek the brackish waters. The estuary of the Trave River, Dassow Lake, shows the same pattern as the Schlei in this regard. It is also beyond doubt that most of the herring found in Kiel Harbor from January to April-- which represent the major resource of the Ellerbeck fishery at this time, and which were designated in Part One of my investigations with the now no longer suitable expression 'Kiel winter herring'-- are identical with those which later migrate to spawn in the Schlei; this is evidenced especially by the very advanced maturation of their testes and ovaries; hence, they should be classed as spring herring. However, a smaller portion of these (doubtless spring) herring do not go to the Schlei, but spawn in salt water, or at least near the mouths of small rivers, in April or May. Dr. MEYER[1] observed such fish in the process of spawning on May 5 and 6, 1878 in the estuary of the Schwentine and in the Eider Canal near Holtenau. Together with the spring herring, albeit in much smaller numbers, especially in February and March, there are large herring with completely undeveloped, spent gonads; and these, again, can only be viewed as spent autumn and winter spawners.

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[1] Dr. H. A. MEYER, Biologische Beobachtungen bei künstlicher Aufzucht des Herings der westlichen Ostsee ['Biological observations on artificially reared herring from the western Baltic'], Berlin 1878, p. 20.

After due consideration of all of these facts, I decided to take the following table, for the present, as my criterion for differentiating autumn and spring spawners. The maturation stages of the sex products are designated by Roman numerals as explained in the introduction.

1- month 2- spring spawners 3- autumn spawners 4- January
5- February 6- March 7- May 8- June 9- July

Monate ①	Frühjahrshering ②	Herbsthering ③
Januar ④	(III) IV (V)	(VII) VII—II
Februar ⑤	(III) IV—V (VI)	II
März ⑥	(IV) V (VI)	(II) II—III
April	(IV) V—VI (VII)	III
Mai ⑦	(V) VI (VII)	(III) III—IV (IV)
Juni ⑧	(V) VI—VII (II)	(III) IV
Juli ⑨	(VI) VII (II)	(IV) IV—V (V)
August	(VII) VII—II (III)	(IV) V (VI)
September	(VII) II (III)	(IV) V—VI (VII)
October	(II) II—III (IV)	(V) VI (VII)
November	(II) III (IV)	(V) VI—VII (II)
December	(III) III—IV (IV)	(VI) VII (II)

Stages in parentheses represent herring which are either very lagging or very advanced for the month in question.

This table is a good reflection of the fact, which has been known for a long time, that herring at all maturation stages can be found in Kiel Bay throughout the year. It is impossible, at least at certain times of year (especially November and December), to draw a sharp boundary between spring and autumn herring.

I can now turn to the actual investigation, in which I considered only those herring listed in the long table with total lengths from 180 to 320 mm. The investigation comprised three parts.

1. Obviously, it would be most advantageous for reaching our goal-- i.e., for demonstrating a connection between form and life cycle-- if we examined only fully ripe spring herring from the Schlei, and only fully ripe autumn/ winter herring from Kiel Bay. This latter stipulation can be achieved only partially, because hitherto I have obtained only few ripe autumn herring. The former requirement is much easier, and has largely been met.

In 1877 and 1878, in the period from March 26 to May 23, I examined 114 adult herring from the Schlei with sex products at stages IV - VII. According to the familiar four-character combinations, 93 of these (= 81 %) belonged to var. b, and 21 (= 19 %) to var. a.

Among these 114 herring, 71 were either in the process of spawning or recently spent. Out of these undoubted spring spawners, 58 (= 82 %) belonged to var. b, and 13 (= 18 %) to var. a.

In November and December 1877/ 78, I examined 39 herring caught with a drift net in the open waters of Kiel Bay, which showed maturation stages V - VII-- i.e., they were definitely autumn spawners. Twenty-five of them (= 64 %) belonged to var. a, and fourteen (= 36 %) to var. b.

Of the 39 herring, 20 were either spawning or newly spent. Thirteen of these (= 65 %) belonged to var. a, and seven (= 35 %) to var. b.

The results of both investigations correspond in indicating that the majority of all spring spawners belong to var. b, and the majority of autumn spawners belong to var. a. However, there is only partial correspondence between form and behavior as regards the location of the fins and anus and the length of the anal fin. If we take complete correspondence =1, the correspondence index is 0.82 for the spring spawners, and only 0.65 for the autumn spawners.

Now let us compare the body forms of the spring and autumn herring in the long table also outside of the spawning periods. Herring are listed for every month; only February, April, and September can be regarded as inadequately represented.

The total number of herring listed with body lengths from 180 to 316 mm is 404. Of these, 261 (= 65 %) belong to var. b, and 143 (= 35 %) to var. a.

Thus, as already observed in my previous investigation, var. a is the minority in Kiel Bay, with a ratio to var. b of 1: 2.

Out of 404 herring of both types, 362 were investigated to determine the maturation stage of their gonads when they were caught. Of these, 258 (= 71 %) were spring spawners, and 104 (= 29 %) were autumn spawners.

Thus, the ratio of autumn spawners to spring spawners is 3: 7.

If we check the correspondence between form and behavior in these last-mentioned 362 individuals, the results are as follows:[1]

var. a autumn spawners.............. 68 = 18 %
var. a spring spawners.............. 47 = 13 %
var. b autumn spawners.............. 35 = 10 %
var. b spring spawners............. 212 = 59 %

Let us also recapitulate these findings for the 114 + 39 = 153 fully ripe herring discussed previously:

var. a autumn spawners.............. 25 = 16 %
var. a spring spawners.............. 21 = 13 %
var. b autumn spawners.............. 14 = 9 %
var. b spring spawners.............. 93 = 62 %

--almost exactly the same percentages.

Thus, the overall result can be described as follows:

Differences exist among the herring of Kiel Bay, on the one hand, with respect to form, and on the other hand, with respect to behavior. The differences of form affect the location of the dorsal and ventral fins, the location of the anus, and the length of the anal fin; the behavioral differences concern the time and place of spawning. Both types of difference coincided in 77 to 78 % of all herring investigated. 17 % of these were autumn spawners in salt water; the dorsal and ventral fins and the anus are located far back, and the anal fin is short. Ca. 60 % were spring spawners in brackish water; the dorsal and ventral fins and the anus are far forward, and the anal fin is long. However, in 22 to 23 % of all the herring investigated, form and behavior do not coincide, so that these fish are actually intermediate between the two races.

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[1] In order to facilitate comparison of these assertions with the long table, spring herring of var. a and autumn herring of var. b are marked with an asterisk in the first column.

It is highly probable that more extensive research will somewhat alter the above percentages. For, relatively too few autumn herring were examined, since the months of September and October, in which a considerable number of herring must spawn, were inadequately represented, because regular fishing in Kiel Bay had not yet begun at this time. On the other hand, a disproportionately large number of individuals were examined for April and May. If the reverse had been the case, and I had examined a disproportionately large number of fish from salt water in the autumn spawning season, then the percentage of autumn herring would have been too large. For, not only the spawning times of the two races are different; fish of each variety, driven by the reproductive instinct, gather at these times in different places. Therefore the autumn spawners will necessarily outnumber any spring spawners associated with them at certain salt water locations in October and November, while spring spawners must outnumber them from April to June in the Schlei. The investigation shows this very clearly. Among 84 individuals caught in open water with a drift net in November and December, 1877, the groupings were:

var. b spring spawners	20 =	23 %
var. b autumn spawners	21 =	25 %
var. a spring spawners	6 =	7 %
var. a autumn spawners	37 =	45 %

Whereas for 98 individuals caught in the Schlei during May, the groupings were:

var. b spring spawners	75 =	77 %
var. b autumn spawners	5 =	5 %
var. a spring spawners	17 =	17 %
var. a autumn spawners	1 =	1 %

In order to find a natural mixture of both forms in a single month, we should have to choose a time when neither race is subject to the drive to gather in a certain area for reproduction, but both experience a common drive for food. Such a time would fall between their respective spawning periods, i.e., either from January to March, or from July to September. The first of these periods, being the main fishing season for herring in Kiel and Eckernförde, is best suited for research. Among sixty randomly selected individuals from large catches taken in Kiel Harbor from March 15 to March 26, 1878, there were the following ratios:

var. a spring spawners	18 =	30 %
var. a autumn spawners	3 =	5 %
var. b spring spawners	6 =	10 %
var. b autumn spawners	33 =	55 %

Notice that the percentage of autumn spawners has risen. Of course, probably also these values will not be completely accurate, because the number of sixty individuals examined is too small. Probably the best approximation of the actual situation can be obtained by taking the mean values between those for March and those for 362 individuals throughout the year: viz., 24, 9, 10, and 57, or 34 % autumn herring and 66 % spring herring.

2. I believe that even the most cautious researcher will concede that some connection between form and behavior has been demonstrated here for autumn and spring herring from Kiel Bay. The next question is whether there are differences also in other characters besides those which have already been considered. The long table, which, for most individuals, lists a number of other traits apart from the combination of four basic characters, will serve excellently to answer this question.

a. I shall begin with the lateral head length. When this measurement is taken as =1 and the total length as =x, the index varies between 5.5 and 3.8. We then have three levels of variation for the lateral head length:

a. 3.8- 4.3, b. 4.4- 4.9, and c. 5.0- 5.5.

As I already demonstrated in Part One, in herring as in all fishes, the relative length of the head is greater in relation to total length in juveniles than it is in older fish. This can also be seen from the table. Levels a, b, and c succeed each other in that order. However, among sexually mature fish this relation is almost absent, so that for the present investigation, it can be neglected. Level a occurred only once in fish more than 180 mm long, so that we are concerned only with levels b and c.

The following short table shows the occurrence of these two levels in the two varieties, spring and autumn herring.

Form.	Untersuchte Zahl. ③	b	c	b : c	
① var. *a* Herbsthering . . .	45	19	26	1 : 1.3	1 : 2
var. *b* Herbsthering . . .	23	4	19	1 : 5	
② var. *a* Frühjahrshering . .	24	9	15	1 : 1.6	1 : 6.4
var. *b* Frühjahrshering . .	117	10	107	1 : 11	

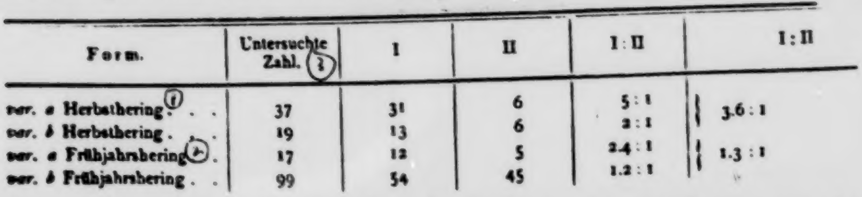
1- autumn herring 2- spring herring 3- number examined

This table shows clearly that level c occurs much more frequently among autumn herring of var. a than among spring herring of var. b, so that there is a considerable difference between the two races in this regard. In the first form, the lateral head length is greater; i.e., it remains at a more juvenile stage.

Moreover-- and this is of no less importance-- notice that those autumn spawners belonging to var. b approximate the autumn spawners of var. a with respect to lateral head length; and conversely, spring spawners of var. a are very close to the true spring herring of var. b.

b. Very similar results are obtained for the height measured at the beginning of the tail[1], regardless of the maturation stage of the sex products. With T= 1000, we have the following levels of variation for the height of the tail: I. 57- 66, II, 67- 76, and III. 77- 86.

This yields the following table:



Form.	Untersuchte Zahl. ③	I	II	I : II	I : II
var. a Herbsthering ① . .	37	31	6	5 : 1	3.6 : 1
var. b Herbsthering . . .	19	13	6	2 : 1	
var. a Frühjahrshering ② .	17	12	5	2.4 : 1	1.3 : 1
var. b Frühjahrshering . .	99	54	45	1.2 : 1	

1- autumn herring 2- spring herring 3- number examined

Accordingly, the height at the end of the tail is smaller in var. a autumn herring than in var. b spring herring; var. b autumn spawners approximate var. a autumn herring; and likewise, var. a spring spawners differ from var. a autumn herring in the direction of var. b spring herring.

c. I define the following levels of variation for the numbers of keel scales:

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[1] Translator's note: Heincke sometimes refers to the 'height at the end of the tail', and sometimes to the 'height at the beginning of the tail'. Both of these seem to be identical with the height at the beginning of the caudal fin. However, to avoid the risk of aggravating the existing confusion, I have translated each reference as it stands.

keel scales between...		total number of
head and ventrals/	ventrals and anus	keel scales
		o. 49—47
o. 32 und 31	o. 19 und 18	α. 46—44
a. 30 und 29	I. 17 und 16	β. 43—41
b. 28 und 27	II. 15 und 14	γ. 40—38
c. 26 und 25	III. 13 und 12	δ. 37—35

['und'= and]

We then have the following two tables:

1. Keel scales between head and ventrals (K_1)

Form.	Untersuchte Zahl. ③	a	b	c	a:(b+c)	
var. a Herbsthering① . .	37	15	22	0	1:1.5	1:1.1
var. b Herbsthering . .	16	10	6	0	1:0.6	
var. a Frühjahrshering② .	23	6	15	2	1:3	1:4.5
var. b Frühjahrshering .	115	19	87	9	1:5	

1- autumn herring 2- spring herring 3- number examined

2. Total number of keel scales ($K_1 + K_2$)

Form.	Untersuchte Zahl ③	α	β	γ	α:(β+γ)	
var. a Herbsthering① . .	37	10	25	2	1:2.7	1:2.7
var. b Herbsthering . .	15	4	11	0	1:2.7	
var. a Frühjahrshering② .	24	2	15	7	1:11	1:10.4
var. b Frühjahrshering .	113	10	72	31	1:10	

1- autumn herring 2- spring herring 3- number examined

These tables show that both the number of keel scales between head and ventrals, and the total number of keel scales are greater in var. a autumn herring than in var. b spring herring. Var. b autumn spawners and var. a spring spawners again show the same behavior in this case as in the case of the head length and the height of the tail; indeed, as far as keel scale numbers is concerned, they are almost identical with the race with which they share the same spawning time.

There is a similar difference between the two races also in the number of keel scales between the ventrals and the anus; however, this difference is very slight, and it is manifested only by the fact that the lowest numbers, 12 and 13, were found somewhat more frequently in spring herring, and the highest, 16- 19, were found somewhat more frequently in autumn herring.

The simultaneous occurrence of relatively large differences in the numbers of keel scales and differences in the four basic characters is explained by the necessary correlation between the location of the anus and ventral fins, and the keel scales. K_1 is obviously directly proportional to the distance to the ventral fin (V); $K_1 + K_2$, to the location of the anus (A); and K_2, to the distance A - V. But A and V are generally larger in var. a than in var. b, so that also the number of keel scales is larger. The distance A - V is almost equal in both forms for combinations such as -aI-; -bII-; -cIII-, etc. It, and with it the number K_2 become very large with combinations such as .cI.; .bI.; .aIII.; or .bIV. Of course, another factor affecting the number of keel scales is the size of the individual scales, which generally seems to be smaller in autumn herring than in spring herring.

d. The long table shows the number of vertebrae for 108 sexually mature individuals. It ranges from 51 to 58, with variations distributed among the four types of herring as follows:

Form.	Untersuchte Zahl. ③	51	53	54	55	56	57	58	(51—55) : (56—58)	
var. a Herbsthering ①	10	—	—	—	3	7	—	—	1 : 2.3	1 : 2
var. b Herbsthering	4	—	—	—	2	1	—	1	1 : 1	
var. a Frühjahrshering ②	15	—	—	—	9	5	1	—	1 : 0.6	1 : 0.9
var. b Frühjahrshering	79	1	1	5	34	34	4	—	1 : 0.9	

1- autumn herring 2- spring herring 3- number examined

The highest number, 58, occurred once, in var. b autumn herring. The lowest, 51, occurred once, in var. b spring herring. The table further shows that in var. a autumn herring, the numbers 56 and 57 predominate over the lower counts, while in var. b spring herring the opposite situation prevails. Those herring falling between both extremes exhibit the same pattern in this as in the other characters.

e. As regards the maximum size of the two herring races, I conjecture that autumn herring generally grow larger than spring herring. Detailed results for thirty individuals with a total length exceeding 250 mm are as follows:

Form	Zahl ③
var. a Herbsthering ①	10
var. b Herbsthering	1
var. a Frühjahrshering ②	8
var. b Frühjahrshering	11

1- autumn herring 2- spring herring 3- number

Such large fish, especially those exceeding 280 mm, are very infrequent, and must be selected carefully from many catches. We see clearly that they include more spring

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than autumn spawners, so that my conjecture was not confirmed by this sample. On the other hand, there is an undeniable relation between body size and the morphological varieties a and b. Of these thirty largest fish, 18 belonged to var. a, and only 12 to var. b. Expressed more precisely, there is a distinct correlation between the distance from the tip of the snout to the anus (A) and total length (T). Individuals in which the former measurement is relatively large (e.g., variation level I) evidently are apt to attain a good size; or else, those which become particularly large for other reasons alter their body shape so that the tail grows less in relation to the trunk. Among 46 herring with a total length over 250 mm, 31 belonged to var. a and 15 to var. b. Twenty-three of these 46 herring have level I for the character 'A'; 21 have II; and two were not investigated for this character. Level III no longer occurs among very large herring; the largest herring with this level of variation measured 242.5 mm.

Since the above correlation is undeniable and level I must occur much more frequently in var. a autumn herring than in var. b spring herring, it is highly probable that examination of a greater number of fish exceeding 250 mm would reveal yet another difference-- in addition to the other differences observed between the two races-- in maximum size.

f. Finally, there seems to be a minor difference in the relative height at the back of the head; for, this measurement is minimally larger in var. a autumn herring than in var. b spring herring. However, this point must be researched more precisely before it can be judged securely, so that I shall leave it aside.

Let us recapitulate. First, it has been demonstrated that the two groups 'var. a autumn herring' and 'var. b spring herring', which together make up more than ca. 78 % (or more than three-quarters) of all herring caught in Kiel Bay, and which differ clearly morphologically and in their spawning behavior, have distinct differences in lateral head length, height at the end of the tail, the number of keel scales, and the number of vertebrae as well as in the four characters of fin locations, location of the anus, and length of the anal fin.

Secondly, we have found that the groupings 'var. a spring spawners' and 'var. b autumn spawners', together comprising ca. 22 % of all herring in Kiel Bay, in which form and behavior do not coincide, show results for the four characters 'head length', 'height of the tail', 'number of keel scales' and 'number of vertebrae' such that var. b autumn spawners approximate var. a autumn herring, and var. a spring spawners approach var. b spring herring.

Before I draw any further conclusions from this very important finding, there is now a pressing question which must be resolved. Are the autumn spawners of var. b the animals of that variety which most resemble var. a in the four characters used originally to differentiate the two varieties, as well as in the four newly investigated characters? And conversely, does the same apply to var. a spring spawners?

This is answered by the following tables.

1. Ventral fin location

Form	Untersucht Zahl ③	a	b	c	a:(b + c)	a:(b + c)
var. a Herbsthering ① .	68	55	13	—	1 : 0.23	1 : 0.85
var. b Herbsthering .	34	—	30	4	1 : 34	
var. a Frühjahrshering ②	47	31	16	—	1 : 0.5	1 : 7
var. b Frühjahrshering .	212	2	179	31	1 : 105	

1- autumn herring 2- spring herring 3- number examined

2. Dorsal fin location

Form	Untersucht Zahl ③	1	2	3	1:(2 + 3)	1 : 2 + 3
var. a Herbsthering ① .	64	20	43	1	1 : 2.2	1 : 3.9
var. b Herbsthering .	35	—	30	5	0 : 35	
var. a Frühjahrshering ②	44	14	29	1	1 : 2.1	1 : 17
var. b Frühjahrshering .	210	—	148	62	0 : 210	

1- autumn herring 2- spring herring 3- number examined

3. Location of the anus

Form	Untersucht Zahl ③	I	II	III	I:(II + III)	I:(II + III)
var. a Herbsthering ① .	58	32	26	—	1 : 0.8	1 : 1.6
var. b Herbsthering .	26	—	22	4	0 : 26	
var. a Frühjahrshering ②	40	20	20	—	1 : 1	1 : 7.4
var. b Frühjahrshering .	179	6	155	18	1 : 29	

1- autumn herring 2- spring herring 3- number examined

4. Length of the base of the anal fin

Form	Untersucht Zahl ③	A	B	C	(A + B) : C	(A + B) : C
var. a Herbsthering ①	57	7	46	4	13 : 1	7.8 : 1
var. b Herbsthering	21	2	14	5	3 : 1	
var. a Frühjahrshering ②	41	13	24	4	9 : 1	6,0 : 1
var. b Frühjahrshering	163	8	130	25	5.5 : 1	

1- autumn herring 2- spring herring 3- number examined

These figures show that for the most part, the groups 'var. b autumn herring' and 'var. a spring herring' meet our expectations. There is an exception as regards the location of the dorsal fin, insofar as levels 1 and (2+3) exhibit a ratio of 1: 2.1 in var. a spring herring, and 1: 2.2 in var. a autumn herring; whereas according to theory, the former ratio should be closer to 0: 210 or 1: 210. However, this is a very minor deviation; even a ratio of 1: 2.3 would meet our expectation.

A more serious discrepancy is in the length of the anal fin in var. b autumn herring. Obviously, the ratio of 3: 1 would have to be between 5.5: 1 and 13: 1 to satisfy theory.

However, these few exceptions will occasion no offense if we notice, while examining the eight short tables, that in all eight characters investigated, all autumn spawners differ from all spring spawners in the same way in which var. a autumn herring and var. b spring herring differ--only less. The results so far, at the end of the second part of this investigation, can be stated as follows:

Among the adult herring in Kiel Bay, there are two races with different behavior: spring spawners and autumn spawners, with a numerical ratio of approximately 1: 2. Parallel with the different behavior, there are morphological differences in eight characters. These morphological differences are considerable and distinct in ca. 78 % of all the herring; in the other 22 %, they are of the same kind, but less considerable and less striking.

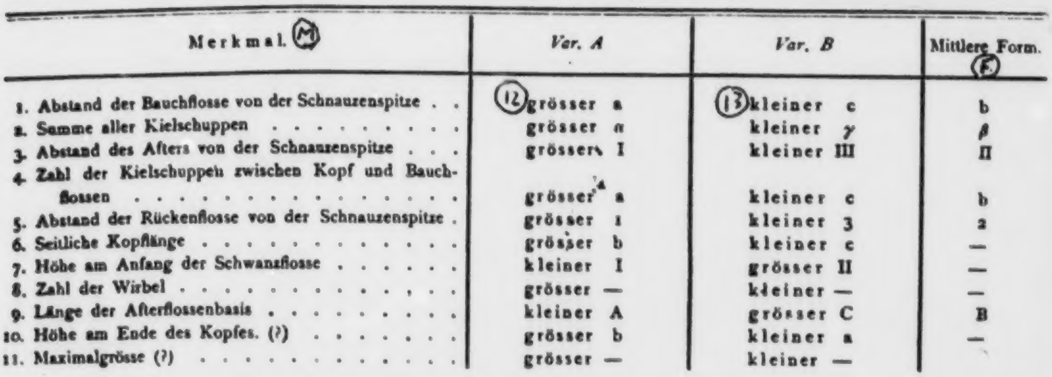
In other words: The process of differentiation which has been completed in the majority of the herring, is still under way in a minority.

3. All previous discussion has been based on the forms designated 'var. a' and 'var. b'. These were based on four characters: the fin locations, the location of the anus, and the length of the anal fin. However, the investigation has revealed that spring and autumn herring differ equally in many other characters, as well. Hence, as a concise formulation of the true differences between the two races, the terms 'var. a' and 'var. b' no longer suffice; we must construct two new terms, 'Var. A' and 'Var. B', comprising all the characters which have been found to differ in the two races.

But first, another question must be resolved: Which characters differ most in the two races, and which differ least? This can be resolved in the following manner.

In the location of the ventral fins, for example, the ratio of the occurrence of level a to that of (a+b) is

1: 0.85 in autumn herring and 1: 7 in spring herring; i.e., the incidence of level a is 8.2 times as high in the former group as in the latter. In the same way, for the length of the anal fin, we find that levels A+B together are 1.2 times as frequent in autumn herring as in spring herring. Hence the difference in the location of the ventral fins is greater than the difference in the length of the anal fin. In general: Characters are ranked by the size of their ratios.



Merkmal. Ⓜ	Var. A	Var. B	Mittlere Form. Ⓕ
1. Abstand der Bauchflosse von der Schnauzenspitze	⑫ grösser a	⑬ kleiner c	b
2. Summe aller Kielschuppen	grösser α	kleiner γ	β
3. Abstand des Afters von der Schnauzenspitze	grösser I	kleiner III	II
4. Zahl der Kielschuppen zwischen Kopf und Bauchflossen	grösser a	kleiner c	b
5. Abstand der Rückenflosse von der Schnauzenspitze	grösser 1	kleiner 3	2
6. Seitliche Kopflänge	grösser b	kleiner c	—
7. Höhe am Anfang der Schwanzflosse	kleiner I	grösser II	—
8. Zahl der Wirbel	grösser —	kleiner —	—
9. Länge der Afterflossenbasis	kleiner A	grösser C	B
10. Höhe am Ende des Kopfes. (?)	grösser b	kleiner a	—
11. Maximalgrösse (?)	grösser —	kleiner —	

M- character F- intermediate form 1- distance from the tip of the snout to the ventral fin 2- total number of keel scales 3- distance from the tip of the snout to the anus 4- number of keel scales between head and ventrals 5- distance from the tip of the snout to the dorsal fin 6- lateral head length 7- height at the origin of the caudal fin 8- number of vertebrae 9- length of the base of the anal fin 10- height at the back of the head 11- maximal height 12- greater 13- smaller

All individuals with a predominant number of features in the left column will now be classified in Var. A, and all those with more features in the right column will be classed in Var. B. Thus, the specimen '211.5. b. I. IcII. IaIIA. bIIIß. 15 July 1878. Kiel. ♂ II very high fat content' falls in Var. A. Three of its characters are intermediate, and two fall in the right column (Var. B), but four-- the predominant portion-- are on the left (Var. A).

Individuals are classed as intermediate between Var. A and Var. B if they have either all characters intermediate or an equal number in the right column and in the left. However, in the latter case, the ranking of the characters should be noted, so that, for example, specimens in which the left-column characters outrank an equal number of right-column characters should still be classed in Var. A, and those with higher-ranking right-column features, in Var. B.

Clearly, certain individuals previously classed in var. a must now be classed in Var. B, and likewise, occasional individuals of var. b will fall into Var. A. But after a moment of reflection, the reader will suppose that these can only be exceptional cases. A careful examination of the tables will persuade him that this inference is in fact correct. Obviously, even this new, more complete differentiation of varieties will be slightly arbitrary; Nature does not recognize any sharp boundaries.

Another defect is that combinations of all eight or nine of the characters in question were investigated in relatively few individuals, so that I was obliged to classify by the same method all of the specimens which had been examined for four, five, six or seven characters.

Also the terms 'autumn herring ' and 'spring herring' which I have been using must now be altered slightly. As already noted previously, there are undoubtedly some herring which can not be designated with either term on the basis of their spawning time-- viz., all those individuals which spawn in January, February, July and August. In the other months, these herring will be approximately in the following stages:

Nov. II (high fat content); IV; IV-V - Dec. II-III; V. - Jan. III; V-VI - Feb. VII; II (very low fat content) - March VII; II (very low fat content). - April II - May IV; IV-V - June V - July VI; VII; - Aug. VII - Sept. II (very low fat content). - Oct. II.[1]

I set apart such individuals with intermediate spawning times, just as I set apart those which are intermediate morphologically. Accordingly, between the three morphological divisions and the three behavioral groups, there are nine conceivable combinations, all of which in fact occur, and they are distributed among ca. 280 adult herring from Kiel Bay as follows:

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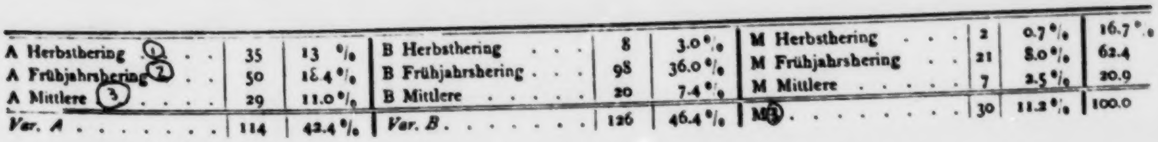
[1] 'Nov. II very low fat content' is definitely a newly spent autumn herring. 'March II. very high fat content' is an autumn herring which spawned in December and has already grown fat again; whereas 'March II. very low fat content' is an individual which spawned in January or February.



A Herbsthering ①	35	13 %	B Herbsthering	8	3.0 %	M Herbsthering	2	0.7 %	16.7 %
A Frühjahrshering ②	50	18.4 %	B Frühjahrshering	98	36.0 %	M Frühjahrshering	21	8.0 %	62.4
A Mittlere ③	29	11.0 %	B Mittlere	20	7.4 %	M Mittlere	7	2.5 %	20.9
Var. A	114	42.4 %	*Var. B*	126	46.4 %	M③	30	11.2 %	100.0

1- autumn herring 2- spring herring 3- intermediate

This represents the final result of the entire investigation, which may be expressed as follows:

1. Half (49 %) of all adult herring in Kiel Bay divide into two races which are completely distinct in form and life cycle, occurring in a numerical ratio of approximately 1: 3 (13: 36). The smaller group comprises ocean herring which spawn from October to December in salt water; the others are coastal herring spawning from March to June, preferentially in brackish water. These two groups are distinctly different in a combination of four to nine characters. The combined variation of form and behavior is expressed by the designations 'A autumn herring' and 'B spring herring'.

2. Another 30 % of all herring in Kiel Bay are either autumn spawners or spring spawners which either have morphological characters intermediate between A and B, or else combine their form and behavior in the reverse fashion, i.e., inconsistently. However, here we find the very same phenomenon observed previously in our investigation of 'var. a spring herring' and 'var. b autumn herring': The 18.4 % 'A spring herring' are much more like B than the 13 % 'A autumn herring', and the same applies conversely to the 3 % 'B

autumn herring'. Therefore, the differentiation which is already complete in 49 % is under way in another 30 %.

3. Finally, 21 % of all herring in Kiel Bay have spawning times between autumn and spring and belong morphologically either to A or to B or to the intermediate group.

A comparison of this final result with the earlier one indicates that the connection between form and behavior emerges just as distinctly as previously, insofar as the majority of autumn spawners have form A, and the majority of spring spawners have form B. However, the number of individuals of form A (42.4 %) is greater than the number which belonged to var. a as previously defined (35 %), because many of these herring of form A spawn in the spring or between seasons.

I believe that this latter fact casts some light on the phylogeny of our herring races; I shall have occasion to return to this point later.

2. Juvenile autumn and spring herring

I define the 'juvenile phase' as the period starting with the acquisition of the definitive herring form and ending at sexual maturity. The size range of the juvenile phase extends from ca. 60 to 180 mm total length.

Naturally, in the case of these juvenile fish, the maturation stage of the genital products can no longer be used as a criterion for differentiating autumn herring and spring herring. Instead, we use the relation between the size of a fish and the date when it was caught. A juvenile already measuring 50 to 60 mm in length in April or May can not possibly be a spring herring from the same year; it must have been born in the autumn or winter. On the other hand, we should be inclined to regard an individual which measures ca. 60 mm in August or September as a spring herring born in April or May.

But a classification based on this method can deliver accurate results only if we have exact knowledge of the growth of herring and if their growth is uniform in every month.

Dr. MEYER, who published the results of his investigations on the growth of herring in the last annual report of the Commission and in the treatise cited above, believes that the average monthly growth of spring herring in their first year is 10 to 12 mm, while that of autumn herring may be somewhat greater. At the same time, however, the same investigations show that growth is distinctly related to the amount of food, and therefore can be very uneven, with fluctuations of perhaps more than 10 mm per month. An autumn herring born in November, but experiencing slow growth can measure just over 100 mm a year later, while a well nourished spring herring born in the following April can also reach a total length of 100 mm by November of the same year.

In months when an abundant food supply of copepods and various kinds of larvae is available, a juvenile herring will grow very fast, and it can be expected to grow correspondingly slowly in months of scarcity.

It follows from this that the size of juveniles in different months can hardly be used as a criterion for differentiating spring and autumn herring. We can now understand the readily observable fact that all sizes from 60 to 180 mm occur together every month of the year. This is not surprising, especially since both spawning seasons extend over several months and, as I have already shown, probably nearly one-fifth of all the herring in Kiel Bay spawn between the two seasons. Hence the only remaining way to differentiate the two varieties in the juvenile phase is the body shape.

If we examine the long table in this connection, it is immediately striking that the body shape of individuals from 60 to 180 mm is not the same as that of adults. Certainly, hardly any differences are noticeable in the number of keel scales and in the four basic characters (fin locations, the location of the anus, and the length of the anal fin); but the lateral head length and body height measurements are very different. Indeed, I have already demonstrated that head length is greater in juveniles than in adults; while only levels c and b occur in adults, level a is important in juveniles and c almost absent. Also the height at the back of the head, and at the origin of the caudal fin is greater in juveniles than in sexually mature herring; b and c, and I and II are dominant variation levels, levels a and I are very infrequent. (Compare Figure 9 with Figure 2 in this regard.)

Since these differences in juveniles compared to adults apply to both sides of the long table, our previous definitions of 'Var. A' and 'Var. B' must be amended to apply to fish with total lengths from 60 to 180 mm. For adults, these definitions were:

Var. A. b — b I — 1 a I A — a —. α.
M. . . . . . . 2 b II B — b —. β.
Var. B. c — a II — 3 c III C — c —. γ.

[M= intermediate]

For juveniles, they should be:

Var. A. a — c II (I) — 1 a I A — a —. α.
M. . . . b — — 2 b II B — b —. β.
Var. B. b — a III — 3 c III C — c —. γ.

Accordingly, among 180 individuals with total lengths from 60 to 180 mm, we have the following distribution:

Var. A. 51 = 28 %
Var. B. 108 = 60 %
M. 21 = 12 %.

These values for A, B, and M-- viz., 28, 60, and 12-- are slightly different from those for adult herring (42, 46, and 12), but not so much as to upset my theory of the distribution of the two races in Kiel Bay. Nobody who weighs the advantages and disadvantages of my research method impartially will be surprised by such minor discrepancies.

A further result is that in every month in which large shoals of juvenile herring occur in the Schlei or Kiel Bay, fish of equal size of both varieties are observed together. Such months are August, September, October, November, January, and March. Juvenile herring of form A are found in the Schlei as well as in Kiel Bay, so that some of the herring born in autumn and winter must move into brackish water at certain times and mix with the spring herring born there.

Dr. MEYER has already called attention to this fact in the last annual report of the Commission (p. 245). It is a very important finding for our understanding of the life of herring, and it can be formulated in general terms as follows: Herring of equal size, regardless of race, have a tendency to gather in large shoals and seek more productive feeding areas. This view is corroborated also by the fact that juvenile sprat of the same size, as well as herring, are found in Kiel Bay all year, and even in the Schlei in certain months, for example in August. It has also been noted above that adults of both herring varieties mingle at certain times of year.

Hence sprat and both races of herring almost always live together in shoals; only the arousal of the reproductive drive separates them, and each of the three moves to specific spawning areas which appeal to its instincts.

3. Autumn and spring herring larvae

The next question which should be discussed is whether the larvae in Kiel Bay which are born in the autumn grow into Var. A, and conversely, those born in the spring develop into Var. B. Our investigation will be based only on fish with total lengths from 20 to 60 mm. The embryonal development of both varieties, and their further growth in the initial period after hatching, up to a size of 20 mm have been studied by Dr. MEYER. Since results of that research are already published,[1] I shall summarize them briefly to the extent that is necessary to understand what follows.

The development of experimentally fertilized eggs of autumn and spring spawners is accelerated by higher temperatures and retarded by lower temperatures.

According to Dr. MEYER's data, the duration of embryonal development is as follows:

autumn herring	spring herring
0-1.0° C	ca. 47-50 days
1-3.5° C ca. 40 days	ca. 33-40 days
7-8° C ca. 15 days	......
10-11° C ca. 11 days	ca. 11 days
14-19° C	ca. 6-8 days

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[1] Dr. H. A. MEYER, op. cit.

When development is slow and the embryo remains inside the egg longer, usually the yolk mass diminishes and the embryo is somewhat larger on hatching. "Spring herring larvae had the following sizes when hatched:

duration of embryonal development	length
7-8 days	4.7-6.0 mm
11-12 days	5.2-6.6 mm
20 days	6.0-6.9 mm
28-35 days	6.1-7.2 mm

Autumn herring, on the average, were longer when hatched. They ranged from 5.4 mm total length as the least measurement after the shortest period of embryonal development (7 days at 10-11° C) to 8.8 mm as the greatest measurement after the longest period (35-40 days at 2-3° C)."

The early growth of herring after hatching was observed by Dr. MEYER in spring herring reared from experimentally fertilized eggs in water from Kiel Bay; they reached a maximum length of 72 mm in five months. After seven to eight weeks, with a length of 25-28 mm, they passed from the larval to the transitional stage; i.e., the transparent, elongated, scaleless body grew more in height, became more thickset, and started to become more similar in scalation and fin locations to adult herring. The average monthly increment was ca. 15 mm.

On the basis of these observations, we can differentiate with reasonable certainty which larvae should be designated as spring, and which as autumn, herring. Of course, one must be careful not to confuse herring larvae with those of other fish. As I have already noted in the last report of the Commission (p. 127), with some practise, herring larvae in the Schlei can be easily differentiated from those of Smelt (Osmerus eperlanus), which occur there at the same time. It is more difficult to differentiate herring larvae and sprat larvae. The latter frequently mingle with the former, especially in summer and winter. They can be differentiated at a glance by their more compact shape and yellowish coloration; further details will be indicated later in a special chapter on sprat. For the present, the first part of the long table will suffice for reliable recognition of herring larvae; it gives a fuller and more precise description than can be expressed through words (cf. Figures 4, 5, and 6).

I observed and examined autumn herring larvae in November, December, January, February, March and April, only in the saline open water of Kiel Bay and Eckernförde Bay. They were sparse in the first three months, and very numerous in the last three. The largest specimen for November (29th) measured 28.8 mm, so that the egg was probably fertilized in early or mid-October. The smallest individual for April (25th) had a total length of 27.0 mm. The largest of all these autumn larvae measured 47 mm in length and was caught in Eckernförde Bay in January, 1877.

Hitherto I have found larvae which definitely originated from spring spawners only in the Schlei, from the middle of May to the end of June. The largest specimen in May measured 30.5 mm in length (Figure 5), and the smallest in June measured 21 mm. The largest of all the spring larvae which I observed measured 31 mm and was caught on June 10; all individuals longer than 31 mm were already in the transitional stage.

The result of these observations is that the offspring of autumn spawners attain a greater size in the larval stage than those of spring spawners.

Quite the same applies to the transitional stage, as well. I observed this stage in spring herring only in the Schlei in June; it began with a total length of 31 mm and was always completed before reaching 44 mm; some invididuals already attained the definitive herring form at a length of 37 mm.

In contrast, the young of autumn herring enter the transitional stage at a length of 44 mm at the earliest (see specimen v. 25 April 1875, from Eckernförde)-- i.e., at a length at which all of the young fish in the Schlei, without exception, have already attained the definitive form. Unfortunately, I was able to obtain only very few specimens of autumn herring in the transitional stage: apart from the individual mentioned above caught on April 25, 1875, there were five caught in salt water in Eckernförde Bay on June 28, 1875 and one from Kiel Harbor on July 26, 1875. However, these suffice to show that some individuals can reach a length of 60 mm without taking on the definitive herring form; while others may already do so at a shorter length, perhaps even 50 mm in exceptional cases (Figure 8).

We can not determine the exact time of year when the transitional stage ends for autumn and spring larvae. It is certain, however, that in the Schlei as well as in Kiel Bay, there are very few young herring which have not acquired their permanent form by August. This indicates that spring herring pass through their larval and transitional stages in May, June, and July. As regards the autumn/ winter brood, the occurrence of individuals in the transitional stage in June and July proves that at least some of these fish, although hatched much earlier, attain the definitive herring form only at the same time as the spring herring. Later, this striking fact will be used to establish an important conclusion.

Before comparing the body form of autumn and winter larvae in greater detail, I should first explain how all herring larvae differ from the adult fish, and how they develop into the definitive form (cf. Figures 2 to 9). Freshly hatched herring larvae are very imperfect creatures. There is no mouth opening, but it appears already in the first few days. The only fins present are the pectorals and one primordial fin fringing the entire body from neck to anus; both of these fins have, in lieu of actual fin rays, only fine, hairlike embryonal filaments. The animal begins to feed only on the fifth day, after consuming the remainder of the yolk; the first blood corpuscles appear on the tenth day. The entire body is completely transparent, with the exception of the eyes.

While the body maintains it slender and transparent form for a long time, the different fins gradually develop, with simultaneous regression of the primordial fin. True fin rays develop as the embryonal filaments, which were originally separated, become fused together in groups; they do not all develop simultaneously, but in succession, so that all fins, without exception, at first have fewer than a full complement of rays.

The dorsal fin develops first. Its relative distance from the tip of the snout is much greater initially than later; the distance diminishes gradually, starting from the -3 position, through levels -2, -1, and 0 successively, and finally reaching level 1, 2, or 3 at the beginning of the transitional stage.

Also the anal and caudal fins separate early. The anal fin, or-- what amounts to the same-- the anus is initially located far back, and shifts gradually from positions such as -V or -IV to I, II, or III at the beginning of the transitional stage. The length of the anal fin, and the number of rays are smaller initially than in the adult fish, usually starting at level 0 or -A and gradually progressing to A, B, or C.

The ventral fins do not form until all other fins are already differentiated. They likewise have only embryonal rays at first, and reach a full complement of nine rays only very late. Their relative location starts far forward at levels g and f; they move back gradually to c, b, and a, and at the beginning of the transitional stage they are located below or behind the origin of the dorsal fin.

The pectorals already appear inside the egg, but maintain their embryonal rays for a very long time, even longer than the ventrals.

The remains of the primordial fin persist for a long time, frequently up to the beginning of the transitional stage.

The body height measurements are very small initially, so that the body is shaped almost like that of an eel (Figure 4). Their formula gradually changes from values such as 7 -f -II to 3aII or 3bII.

The lateral head length is very small at first; it starts at levels such as g and e, and gradually rises to c, b, and a. Level a represents the maximal size of this measurement; however, this level occurs only in herring which have completed the transitional stage and have a total length not exceeding 180 mm. Afterwards the head length becomes smaller again, as already shown above.

Scales and keel scales are the last external parts of the herring body to develop. When they are fully formed and the body has also assumed a more thickset shape, the transitional stage is completed. Whereas the larval stage ends when the anus and fins have reached their definitive locations.

The permanent number of fully formed vertebrae is attained already in the larval stage.

The swim bladder is not yet present at the time of hatching, and initially exhibits a globose shape in larvae.

The long table lists 53 autumn herring larvae plus 7 individuals in the transitional stage, and 11 spring herring larvae plus 10 in the transitional stage.

Let us compare the two varieties more closely. In the long table, all young autumn herring are on the left; all spring herring are listed on the right, opposite individuals of the same size. The comparison facilitated by this arrangement yields the following results:

1. The offspring of autumn spawners lag behind young spring herring of the same size in almost all external characters until they reach the definitive herring form.

In the offspring of autumn herring,

1. the lateral head length is shorter;

2. the three measurements of body height are smaller;

3. the dorsal fin is located farther back;

4. the anus is located farther back;

5. the base of the anal fin is shorter;

6. the ventral fins develop later (only at a total length of 28 mm, compared with 25 mm for spring herring larvae); and

7. scales and keel scales form later.

This result merely expresses more precisely the statement that autumn herring grow larger than spring herring in the larval and transitional stages. Figures 4 and 5 vs. 6 and 7 illustrate the differences in the development of the two races.

The location of the ventral fins in the two varieties merits special attention. For in this respect, spring and autumn herring are almost identical, whereas there are considerable differences in all other characters. Thus, for example, an autumn larva with a total length of 32 mm caught in Kiel Bay on December 4, 1877 has the formula 7; -3c -II -A; V.3-4. A spring herring of the same size caught in the transitional stage in the Schlei on June 23, 1874 has the formula 5; 1cI-; V.9. The location of the ventral fin is the same in both fish, but its stage of development is quite different. From this peculiar fact, it follows that the position of the ventral fin relative to the dorsal is different *a priori* in the two varieties. Autumn herring larvae have formulae such as -3d; -2b; -1a; while spring herring larvae have formulae such as -1d; -1c; 1c, etc.

2. After completion of the larval and transitional stages, the body structure of the autumn brood passes inevitably into body form A (autumn herring); whereas the different body structure of the spring brood becomes form B (spring herring).

This is especially clear with respect to the location of the fins and anus. In the autumn brood, the ventral fin already occupies the extreme anterior position, viz., variation level a, at a time when the lagging dorsal fin has only reached -2, -1, or 0. If the dorsal also were to reach its extreme anterior position, viz., 3, during subsequent development, this would give the combination 3a. However, this apparently conflicts with certain as yet unknown laws of body structure, since it is extremely rare in herring. Hence, the autumn brood should preferably reach the combination 1a, 2a, or 1b.

Conversely, a majority of young spring herring, on which the dorsal fin is located farther forward from the start than on the autumn brood, will reach combinations 1c, 2c, 1b to 2b, 3b, or 3c.[1]

As regards the other characters, it is understandable that during the development of the autumn brood, the more posterior location of the anus, the shorter length of the anal fin, and the shorter height at the beginning of the tail lead to levels I, A, and I, which are characteristic of Var. A. Thus, in these characters as well as in the fin locations, adult herring of form A exhibit embryonal qualities.

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[1] Note: Compare Part One, p. 100.

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The lateral head length and the height at the back of the head show a somewhat different pattern.

We know that the lateral head length is greater in adult herring of form A than in form B (p. 11). However, the reverse is true in the larval and transitional stages; this measurement is shorter in the autumn brood than in spring herring. Thus, to some extent, head length stands in contrast to the other characters, insofar as autumn herring lag behind spring herring in the larval and transitional stages, but the latter are behind the former as adults. However, this inconsistency is only apparent. For, the head length differs from the other characters, in that it does not follow a continuous increasing or decreasing course of development, but rises to a certain peak (a) in all herring from 20 to 60 mm (cf. Figures 7 and 8) and then gradually falls back. Thus, we must differentiate two different periods of development, one ascending from f to a, and the other descending from a to c. Once this is clearly understood, we find that autumn herring reach the same maximum head length as spring herring, but in other respects lag behind the spring herring as adults, as well as in the larval and transitional stages. The autumn herring remain at an embryonal stage in the location of dorsal fin and anus; in the lateral head length, they develop beyond the embryonal stage, but remain at a juvenile stage.

The very same situation applies to the height at the back of the head. At the same time when the head length reaches its maximal level (a), the height of the head peaks at c. Evidently both measurements are related, as we can readily understand if we consider that given the fusiform shape of the herring, a greater head length almost inevitably involves a greater height at the back of the head.

The differences between spring and autumn brood in their maximal height are almost fully compensated during the course of development, so that beyond 50 mm total length, hardly any difference is perceptible.

A greater number of keel scales are formed in Var. A because the distances from the tip of the snout to the ventrals and anus are greater from the start than in form B.

As noted above, the definitive number of vertebrae is attained in the larval stage. Since autumn herring larvae not only are longer than spring larvae, but at the same time also have a smaller lateral head length, more space is left for the growth of the vertebrae. Enlargement of the vertebrae themselves would impair the flexibility of the body, so that it is understandable if the number of vertebrae increases and becomes greater than in spring larvae. Of five larvae measuring from 30.5 to 33 mm in length caught in December, 1877, two had 56 vertebrae, one had 55, one 57, and one 58.

Although the question whether the larvae of autumn spawners will assume body form A and those of spring spawners will assume body form B has now been answered affirmatively, we can still assume that there are exceptions. Otherwise, how should we explain the large number of adult spring herring with body form A which were found in Kiel Bay (above, p. 15)?

Perhaps young, fully developed herring from 40 to 60 mm total length, which occur in large numbers in August in the salt water of Kiel Bay, can be informative in this connection. They always include a considerable number of fully formed individuals which, in spite of their small size, exhibit chiefly characters of form A, although we should expect to find form B. Several of these individuals are listed on the left half of the long table. Perhaps their deviant behavior can be explained by assuming that they are the offspring of spring herring which spawn from March to May, not in the Schlei, but in the salt water of Kiel Bay, especially in estuaries. It has already been mentioned above that such herring exist. The ambient conditions to which the brood are exposed during their development in salt water, which are different from conditions in the Schlei, would then alter the form of these fish. I shall return to this point later. According to the table, some fully formed herring with a total length of 40 to 60 mm with characters of form A occur in August also in the Schlei.[1] This may demonstrate that the ambient conditions of development in brackish water do not lead to form B in every case. This too is not essentially surprising, since the differences between A and B are small, and can be obscured in various characters by very minor deviations. Thus, a spring larva which passes through level 1c in the location of the dorsal and ventral fins will usually reach 2c, 2b, or 3c. However, sometimes a minor deviation in the ventral fin location will lead to the formula 1b, etc.

Considerable and profound disturbances in the normal development of body form probably occur in herring, as in other animals. For example, a prolonged period of undernourishment will inevitably lead to emaciation of the entire body, especially parts without extensive bone. Therefore, in poorly nourished indivuals, the head, with its well developed skeleton, will be very large in relation to the body and especially the tail, and it should not be surprising if the formula of the overall body form is unusual. Apparently in such cases form B frequently becomes form A. The retarded growth of the tail causes a very posterior location of the anus and the dorsal and ventral fins, and the disproportionately large head exhibits a greater relative length and height, while the height at the end of the tail is short. A small, very emaciated herring reared in an aquarium by Dr. MEYER typifies this condition. From July 25, 1875 to June 1, 1876, this individual grew from approximately 36 mm long to 68 mm, or barely 3 mm per month. Its formula is 68 - a - 1 - 3cI - laIC.

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[1] E.g., 41.7 - a - 1 - 3bII - 1aIIB - 20 Aug. 78 - Schlei.

I also found emaciated individuals in the Schlei in November, 1874. One of them, measuring 58 mm long, is listed in the table: 58 - a - 1 - 3cII - 1bIIB - III - 26 Nov. 74 Schlei. This individual, evidently a spring herring with retarded growth, still belongs to form B, but closely approximates form A, especially if we disregard the number of keel scales, which can not change as a result of emaciation.

The end result of this section can be summarized as follows:

1. Larvae of autumn and spring herring are almost always very different from each other with respect to body shape. In the adult stage, these differences almost always lead to the two forms A and B, with A characteristic of autumn herring and B characteristic of spring herring. Only major, quite abnormal disturbances of growth during the juvenile stage, which of course occur only in few individuals, can obscure or eliminate these differences.

2. The most important of all the characters which differentiate the two races is the total number of keel scales, because this remains constant even with very abnormal conditions of growth.

3. Overall, the differences between spring and autumn herring, in their life cycle as well as their body form, are hereditary.

4. These differences between the two varieties develop in the period between hatching from the egg and attaining the definitive herring form.

4. The causes of racial differences

1. The result of the preceding section, viz., that racial differences develop in the larval stage, obliges us to seek the cause of those differences in the ambient conditions to which larvae of both varieties are exposed in the period after hatching.

Dr. MEYER has already attempted an exact determination of these conditions in the last annual report of the Commission. The fact that within certain limits, the rate of development increases in direct proportion with the temperature[1] suggests that the development of the larva towards the definitive herring form is also related to temperature, and specifically, that lower temperatures retard, and higher temperatures accelerate development.

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[1] Note: The same correlation is known also in the development of many other animals. SEMPER discusses this interesting fact and its important relations with other phenomena in an excellent work which is as scientific as it is popular: Die natürlichen Existenzbedingungen der Thiere ['The natural conditions of the life of animals'], International Scientific Library, BROCKHAUS, Leipzig 1880,

This hypothesis is now more probable; in fact, continued research by Dr. MEYER and myself allows us to describe the causes of the development of varieties more exactly in the case of herring than has been possible hitherto in the case of any other free-living animals, with very few exceptions.

a. With regard to salinity and temperatures during the spring and autumn spawning seasons, Dr. MEYER obtained the following findings:

In the Schlei, according to measurements taken from March to July inclusively for three years (1875-1877), salinity averaged slightly less than 0.50 %. The temperature was low at first, ca. 2° C, but increased very quickly, reaching almost 20° C by the end of the spawning season. The current was weak.

In Kiel Bay, in the autumn spawning season from August to December inclusively, salinity was ca. 1.65 % at the surface, and somewhat higher in deep water. The temperature at the beginning of the spawning season in August was as high as at the end of the spring spawning season, averaging ca. 20°; but it fell very rapidly to 2° C, and even lower in January and February, reaching 1° and 0° C. The current was

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considerable at all spawning sites. In the shallow coastal areas of Kiel Bay, where a number of herring spawn in the spring, salinity and temperature conditions were intermediate between those of spring in the Schlei and autumn levels in salt water. Undoubtedly, conditions in the estuaries would approximate those of brackish water even more closely.

b. With regard to larval development, I have obtained the following findings:

In the Schlei, herring pass through their larval and intermediate stages from April to July, i.e., under the physical conditions just described. In Kiel Bay, the autumn and winter brood pass through the same stages from October to July of the following year.

Hence, as already mentioned earlier, the development of the two races begins at very different times, but ends at nearly the same time. Undoubtedly this entails that the autumn and winter brood attain the definitive herring form much more slowly than the spring brood in the Schlei. This also is consistent with the fact that so many larvae of form A occur in April in Kiel Bay. The numbers of herring spawning in January and February are so small by comparison, that all of those April larvae could hardly have descended from these fish alone; instead, we must assume that the predominant majority of April larvae are individuals which hatched in the autumn of the previous year and were already larvae in November and December, but grew only very little in the coldest months from January to March. On this assumption, it is understandable that I did not observe transitional stages of autumn and winter herring before the end of April, although large larvae were already caught in November.

All of this evidence indicates that temperature should be regarded as the main reason for the rapid development of larvae in the Schlei, and for the fact that the development of autumn and winter larvae takes almost twice as long. Hence, larval development, as well as embryonal development, is actually accelerated by rising temperatures and retarded by falling temperatures.

The spring brood hatched in April is exposed to constantly rising temperatures which peak in June and July simultaneously with the termination of the larval stage; whereas autumn herring hatched in October and November, although at first exposed to higher temperatures than herring hatched in April in the Schlei, are surrounded soon by water temperatures falling steadily to zero. Their development, which may be rather fast initially--individuals with a total length of 28 mm are already found in November-- becomes progressively slower, and probably ceases completely for a while[1], to quicken its pace again only when the water temperature in the bay rises, i.e., in April and May. From then on, it is only a short time until development is completed.

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[1] SEMPER's experiments with Lymnaeus stagnalis have shown that also in that species, very low temperatures can arrest growth completely, without otherwise harming the animal; loc. cit. p. 133.

Another feature of the embryonal development of herring observed by Dr. MEYER is of considerable interest. As the duration of development becomes longer because of low temperatures, the relative size of the yolk tends to decrease with a corresponding increase in the length of the larva when hatched. In this way, total length at hatching can vary from 4.7 to 7.2 mm for spring herring and from 5.4 to 8.8 mm for autumn herring. It is striking that the larvae survive this situation just as embryoes do inside the egg. Larvae of form A, which develop more slowly under the influence of the cold, are larger than the faster growing larvae of form B. Now, it would be very important to inquire whether embryoes which are larger or smaller when hatched also show the same differences in the relative sizes of respective body parts as the (larger) larvae of form A and the (smaller) larvae of form B. Since separate fins are not yet differentiated in freshly hatched individuals, here we can only consider the location of the anus, the head length, and the body height measurements. Unfortunately, very few measurements have yet been made in this connection, and even these relate only to the location of the anus. However, they yield a result which calls for further investigations on this question. According to Dr. MEYER's[1] data, two embryoes hatched after ten days at 10-11° C from experimentally fertilized eggs of spring herring measured 6.4 and 6.6 mm total length and had the formula -III for the location of the anus. Five hatchlings from experimentally fertilized eggs of autumn spawners, after 15 to 40 days at temperatures from 8 to 2.5° C, measured 6.6 to 8.8 mm and had their anus located at positions -V and -IV. Hence, the differences in the location of the anus actually already exist from the start. If more extensive research confirms the regularity of this result, it would be very interesting. For we have already seen above that there is an obvious correlation between the location of the anus and body size, insofar as the largest of all the herring which I investigated, with total lengths from 260 to 320 mm, were characterized by a very posterior location of the anus, or-- what amounts to the same-- a short tail.

The references to 'retarded' and 'accelerated development' in the preceding discussion are much too vague to give a clear picture of the effect of external conditions on a growing organism; indeed, they are even partly false. For if we consider the differences occurring in the location of the ventral fins in autumn and spring larvae, we find that in this character, the autumn larvae are in phase with the spring larvae and, not infrequently, even ahead of them. The same applies to the increase in body weight; it is definitely not retarded in autumn larvae to the same extent as the growth of respective body measurements. If it were-- if the overall effect of the external conditions were to retard every aspect of development-- then an autumn larva observed in May and probably hatched already in November or December should look exactly the same as a spring larva of the same size hatched in April.

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[1] MEYER, Biologische Beobachtungen... ['Biological observations...'] etc., p. 10.

It also seems at least doubtful whether the water temperature is the only cause of varietal differences. Certainly also differences in salinity, the strength of the current, and the food supply could alter herring larvae. In order to approach this problem more closely, I should like once again to compare the two larval forms. Careful observation reveals the following differences between them:

1. They show different degrees of differentiation in bodies of equal size.

This is manifested, first, by the fact that the spring larva already has a number of organs at a size at which they are still absent-- or better, still not differentiated-- in the autumn larva. These include scales, keel scales, swim bladder, fins and fin rays, etc. The lesser differentiation of the autumn larvae is also manifested by the fact that they are still at variation levels which spring larvae of the same size have already superceded in (anal and dorsal) fin locations and body height.

2. They show different types of differentiation at the same size.

This is shown mainly by the fact that several body measurements grow at different rates in the two types of larvae, both in relation to one another and in relation to total length. This is the actual reason why an autumn larva with retarded development does not eventually overtake the spring brood, but develops into a different race.

Thus, for example, the tail grows in length much less in form A than in form B, so that it is shorter absolutely at the end of growth. As a result, not only the anus, but also the dorsal fin are located farther back in form A. Greater or lesser growth of respective measurements is expressed in my symbols by the fact that, for example, the dorsal fin passes through a greater number of variation levels in form B than in form A.

The different type of differentiation of the two types of larvae can be seen, even more distinctly than by comparing individual measurements, if we investigate the growth of different measurements relative to each other. For example, the growth of V in relation D is quite different in form A than in form B. The location of the ventral fin passes through more levels of variation in autumn larvae than in spring larvae, but exactly the opposite situation occurs in the case of the dorsal fin; as a result, the growth ratio of V and D is exactly reversed in one type of larva compared to the other. This, then, is the ultimate explanation of the persisting difference in the relative location of the dorsal and ventral fins, which was one of the major differences between the two races.

Now, the first of these two differences-- namely, different degrees of differentiation-- should be ascribed to temperature. Thus, lower temperatures retard the differentiation of the organs in herring larvae, and higher temperatures accelerate it.

This is not surprising. It merely confirms a universal law of organization which, expressed in its simplest form, states that the higher the temperature[1], the more energetic metabolism becomes. The hot tropical sun causes the pulse of life to beat faster, and everything matures more quickly. There is a greater total life force, and its bodily expression is a greater division of labor, a more manifold development of organs. Hence the completeness of tropical creation, the abundance of families, genera, and species. In the North, however, simplicity and uniformity prevail.

The growth of the entire body seems to be related to the degree of differentiation in such a way that animals which, in result of high temperatures, have a lively metabolism and a greater division of labor in their organs, are smaller under otherwise equal conditions than those with a simpler structure and slower metabolism. The giants of the animal world, the Whales, occur preferentially in cold regions; such hot-blooded, fast-flying, dwarflike creatures as hummingbirds occur in torrid zones. At lower temperatures in the organism, food is utilized more to augment already existing cells; at higher temperatures, it is oxydized more quickly, and this also stimulates more rapid differentiation.

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[1] to a certain extent, of course.

If this rule exists in Nature, it is manifested also in our two herring races. Not only do autumn larvae show a lesser level of differentiation than spring larvae of equal size; there are also many autumn larvae in the long table which are even less differentiated than smaller-sized spring larvae. Later I shall show that the autumn spawners in the North Sea, which belong to Var. A but have developed the characters of this variety still further, at the same time surpass all other herring in size.

Obviously, the amount of food consumed by each of the two larval forms during their growth will play an important role. However, we can not yet make any specific statement on this subject. We should probably assume that autumn larvae have a surplus, rather than a shortage, of food during the winter months, so that we can hardly suppose that their growth is arrested by hunger. Probably the spring larvae find more abundant food than autumn larvae at every stage of their development. Otherwise we can hardly understand why the latter reach a length of 40 to 50 mm in three months, while larvae of form A only reach 60 mm in six months or perhaps even longer.[1]

The other difference between the two types of larvae, which consists in the kind of differentiation, probably results less from differences of temperature than from differences in salinity and the strength of the current. It is obvious that major differences in the length of the tail, the height of the body, and fin locations are important for the locomotion of the larva. However, the larva must move differently in water with higher salinity and therefore with a higher specific weight, than in the lighter brackish element. In order to maintain the equilibrium of the body, certain groups of muscles must be exerted more, inducing differential growth of certain parts of the body. Also the amount of movement of the water will be an important factor.

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[1] As regards the influence of temperature on the growth of animals, I should note that in the views which I have just expressed, I am to some extent in disagreement with SEMPER. The latter author adduces (loc. cit. p. 133) that according to his experiments with Lymnaeus stagnalis, very low temperatures arrest the growth of this species completely. He further adduces that for the same reasons, varieties of animal species which inhabit the high Arctic or high mountain ranges are always smaller than their relatives living with higher temperatures. However, the herring races, and many other fishes as well-- cod, for example, not to mention the Arctic whales-- should prove that the latter situation is not universal. While it is clear and undoubtedly true that very low temperatures can arrest completely the differentiation of the elementary parts and thus also reduce growth to zero, I still believe that my view of the action of temperature is more accurate than SEMPER's: As long as the temperature does not fall so low as to arrest completely the differentiation of the elementary parts in a given animal, the effect of the low temperature will be manifested rather in an acceleration of the growth of the individual-- provided that the greater food supply needed for this is present and accessible to the individual. If food is lacking-- and that may frequently result from low temperatures, insofar as they decimate the food animals-- then, of course, there will be inhibition of growth, as well as less differentiation. My view is probably supported also by the fact that according to Dr. MEYER's observations, the average size of larvae hatched from eggs incubated in cold water was greater than that of those from eggs kept in warm water. It can hardly be assumed that the eggs in the first experiment were larger, since some of the eggs used in both experiments came from the same fish. Growth was really greater in the cold-reared animals, since the amount of yolk remaining was almost always smaller. It is obvious that the question of the influence of temperature is not yet ready for a verdict. But in any case, in all questions relating to growth, the amount of food taken up should be the first consideration.

Every ichthyologist knows how widely the external form of the body of fish varies within the same species; my investigations have shown this not only in the case of herring with respect to fin locations, but in many other members of the family Clupeidae and of the Baltic fauna.

It is a rule almost without exception that when one of two varieties of a species, or two species of a genus, lives in salt water and the other lives in brackish or fresh water, the latter not only is smaller, but exhibits a more compact body structure and greater height than the larger and more slender ocean form. This is nowhere more striking than in the three European species of the genus _Gasterosteus_. _G. spinachia_ has a large, elongated, low body with 13-16 dorsal spines, and inhabits only salt water; _G. pungitius_ is also slender, with 7-12 dorsal spines, and lives partly in salt water and partly in fresh water, but mainly in the former, where this species, too, has a more slender form. Finally, Gasteroceus aculeatus, the Threespine Stickleback, also lives in the sea, but advances farthest of all three species into fresh water. Its body form is the most compact, but it is very variable; fish living in salt water are very elongated and large, those in fresh water are generally shorter and smaller.

I could cite several other similar examples from my own experience, but I shall reserve these for a subsequent, more detailed work on the formation of varieties and species. However, I shall mention here two studies by other authors which are extremely important for the questions under discussion.

One is by FATIO[1], Über die Veränderlichkeit der Arten, erläutert durch das Beispiel gewisser Fische ['On the variability of species, as exemplified by certain Fishes']. The author cites a number of freshwater fishes which vary their form depending on the quality of the water or the region where they live, such as Leuciscus rutilus, Salmo fario, Salmo lacustris, Perca fluviatilis, Squalius cephalus, and Alburnus lucidus. The latter, for example, has two varieties: An elongate form with a more slanted snout inhabits and forages the surface layers of the sea; the other, taller form with a straighter snout lives at medium depths. This last observation by FATIO suggests that the greater movement of the surface water may be the reason for the more slender body shape. This would apply to our case as well, since the surface layers of the open sea are obviously exposed to stronger currents than, e.g., the water in the Schlei or Dassow Lake. This would also be consistent with Dr. MEYER's observation that the currents are stronger at the spawning grounds of autumn herring than at those of spring herring.

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[1] Bibliothèque Universelle: Archives des Sciences, tome 58 page 185. 1877.

The other study is VLAD. SCHMANKEWITSCH, _Zur Kenntniss des Einflusses der äussern Lebensbedingungen auf die Organisation der Thiere_ ['Towards the knowledge of the influence of the external conditions of life on the organization of animals'].[1] This is a very erudite work which has already been the subject of considerable discussion in Darwinian treatises, and is most instructive precisely for the present study.

SCHMANKEWITSCH performed experimental studies on the influence of saline solutions of different concentrations on the development of certain phyllopods (_Daphnia rectirostris_, _Branchipus ferox_, and _Artemia salina_). He observed that changing the concentration of the saline solution induced visible changes in the organization of the animals, manifested chiefly in the shape of the antennae, especially the palpi, the number of postabdominal lateral spines, the color of the body and of overwintering eggs, the pinnation of the swimming hairs, etc. Through his own experiments, SCHMANKEWITSCH was able to extend these changes until *Artemia salina* converted with increasing salinity into *Artemia milhausenii*, or with gradually decreasing salinity into the genus *Branchipus*.

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[1] _Zeitschrift für wissenschaftliche Zoologie_ [Journal of scientific zoology] vol. 29, p. 429.

For our purpose, the following findings from this excellent study merit special attention:

1. The freshwater summer form of *Daphnia rectirostris* becomes an autumn form in salt water.

2. Saltwater specimens of *Daphnia rectirostris* are to a certain extent downgraded, even retrogressive forms of the freshwater type. This change is proportional to the salinity. The freshwater specimens have a period in their juvenile stage when they resemble mature saltwater specimens in the characters which differentiate the two forms.

3. *Artemia* (living in salt water) and *Branchipus* (chiefly in fresh water) exhibit the following differences: *Artemia* has a much more prolonged larval stage than *Branchipus*, and the difference is directly correlated with the salinity of the water in which they live. Frequently the larvae are already sexually mature.

The reader by now will have noticed the extensive correspondence between the development of our herring larvae and that of SCHMANKEWITSCH's Phyllopoda. In both cases, the development of the body is inhibited; SCHMANKEWITSCH sees the salinity as the cause, while I regard the temperature as responsible. The most remarkable point is that in both cases, a spring or summer form became an autumn form.

Such similar observations in completely different sectors of the Animal Kingdom call for additional, more exact research. Perhaps then we can determine more precisely which morphological changes should be ascribed respectively to temperature, salinity, and the strength of the current. Certainly it will never be possible to differentiate precisely the effects of these different factors, since they are all very closely related.

5. Spawning periodicity

I have already anticipated the most important results of this chapter; here I shall merely describe the method of the research, and present the evidence.

As I soon discovered, there is only one exact method for determining whether a particular form of herring spawns once a year or twice: One must examine a large number of adult herring at regular intervals in the same year at the same location to ascertain the maturation stage of their sex products, and thus observe the gradual process of ripening. At the same time, the spawning periods should be noted as precisely as possible.

I undertook this task from November, 1877 to August, 1878. Once or twice in almost every month, I examined a number of herring (20- 100) from the same catch, recording the size of all specimens, and the varietal identity of many.

Unfortunately, it is very difficult to obtain herring from Kiel Bay from June to the end of October, because the regular fishery does not operate at this time and only private expeditions can offer assistance. This explains some gaps in the sequence of my observations.

As I have already mentioned, Dr. MEYER and I observed herring spawning in the area of Kiel Bay in all months of the year with the exception of July, August, and September; the actual spawning months are April and May in spring and October and November in autumn.

For our present inquiry, the period after spawning is far more important than the spawning time. The behavior of herring in this period is the key to solving our problem. Unfortunately, observing that behavior is one of the most difficult tasks of herring research; no other period in the life of herring is more difficult. After reproduction, the herring disappear abruptly, and most unfortunately, fishermen do not consider it worth while to pursue the spent, emaciated fish-- hence, as already mentioned, there is a gap in our sampling of Kiel Bay until the end of October.

However, through the efforts of the Commission, we were able, albeit at great expense, to obtain a considerable number of adult herring from Kiel Harbor in July and August of 1878. There were also herring from the Schlei caught at the end of May in the same year, which were freshly spent.

Almost without exception, these fish caught in three successive months belonged to Var. B. From this we can already deduce with considerable certainty that the herring wandering around in the salt water of Kiel Bay in July and August were the same fish which had spawned in the Schlei in April and May and departed from this inland body of water directly afterwards. This was fully confirmed by the fact that the herring in Kiel Harbor in July and August were spent, and exhibited the same maturation stage as the newly spent herring in the Schlei. However, they differed strikingly in another respect: The fish caught at the end of May in the vicinity of their spawning grounds in the Schlei were very emaciated, whereas those caught in Kiel Harbor in July and August were quite extraordinarily fat, so much so that when they were pierced with a needle, fatty fluid emerged immediately, and the entrails were hardly discernible beneath an enormous covering of fat.

This interesting finding demonstrates that for spring herring, the first three months after the end of spawning are not devoted immediately to developing new sex products, but initially to recovering strength and storing fat. Thus,

with reference to the development of eggs and sperm, the first quarter after spawning represents a resting period; with reference to feeding, it is a fattening period.

Some herring caught in Eckernförde Bay in September show that the fattening period can extend into this month. The development of new sex products seems to start only in October, when the ovaries, which were previously reddish and collapsed, take on a dark vinous color and a more stretched appearance, and at the same time, under a magnifying glass, a granular texture from the newly formed eggs.

The autumn herring, which mingle with the riper spring herring after spawning and are therefore easier to observe, behave in exactly the same way as spring herring. While spent autumn herring are extraordinarily emaciated in November, they are already very fat in December. Their period of rest and fattening extends at least to the end of March, since all of the specimens of form A which I examined in this month were very fat, but they had not yet progressed beyond stage two in the maturation of their sex products.

The very fact that in both herring races in Kiel Bay, there is a pause of three or four months in the development of the sex products constitutes sufficient proof that each herring spawns only once a year. If a spring herring were to spawn a second time in the autumn, it would have to progress through stages II to VI in at most eight weeks, and the same would apply to the autumn herring. But such a rapid maturation of eggs and sperm, if it really took place, should have been immediately recognizable in regular monthly samples from the same location, and this certainly was not the case.

In order to make this quite clear to the reader, I shall present the results of my investigations of the sex products in the table below.

Maturation stages I to VII are divided here into three approximately equivalent levels, as follows: I, II, VII -- II-III, III, IV, IV-V -- V, VI, VI-VII.

Thus, the first level comprises all adult herring which either have completely undeveloped gonads (i.e., they have never spawned) or are newly spent and in the resting stage. The third level comprises individuals which are nearly or fully ripe, or spawning; and finally, the second level comprises herring with their sex products at a distinctly advanced phase of maturation, from stage II to V.

The figures on this table fully correspond with the assumption of a yearly spawning cycle.

Level III-- herring which are spawning or almost ripe-- is represented by greater numbers twice a year. In April and May, it comprises 30-55 % of the total sample; in November, 10 %. The lowest numbers of this level occur in December and in July and August, directly following the two spawning seasons.

Zeit des Fanges. ①	Untersuchte Zahl ②	Stufen der Reife kommen vor: ③ Zahl ④ I	II	III	Procente % ⑤ I	II	III	Ort des Fanges ⑥
1877 November (5.—29.)	109	53	46	10	48	42	10	Kieler Hafen⑫
December (2.). . .	58	19	39	0	32	68	0	Kieler Hafen
1878⑦Januar (29.). . . .	63	12	48	3	19	76	5	Kieler Hafen
⑧März (15.—16.) . .	101	51	45	5	50	45	5	Kieler Hafen
März (18.)	37	2	31	4	5	84	11	Schlei
März (26.)	30	4	19	7	13	64	23	Schlei
April (8.).	10	3	4	3	30	40	30	Kieler Hafen
⑨Mai (4.)	40	8	10	22	20	25	55	Schlei
Mai (16.)	33	27	0	6	82	0	18	Schlei
⑩Juli (1.—31.) . . .	35	32	3	0	91	9	0	Kieler Hafen
August (10.—17.) .	14	14	0	0	100	0	0	Kieler Hafen
⑪ Summa.	530							

Key: 1- date of catch 2- number examined 3- levels of ripeness occurring 4- number 5- per cent 6- site of catch 7- January 8- March 9- May 10- July 11- total 12- Kiel Harbor

Spent herring in the resting period are also found in greater numbers twice a year, viz., in the first three or four months after each spawning season, i.e., November to March and May to August.

Level II (stages III to V inclusively) was represented in every month investigated except August, with the highest numbers from December to March, i.e., in the months preceding the spring spawning period.

The absence of partly ripened herring in August is only apparent. The material collected by Consul LORENZEN in Eckernförde, who was assigned by the Commission to make scheduled fishing expeditions in every season for several years, almost always included isolated adult herring with maturation stages III to V from July to September. Of course, these ripening autumn spawners were infrequent. However, also spring spawners, which are spent at this time, were infrequent, so that the entire phenomenon must be explained by assuming that both races avoid the bays near Kiel and Eckernförde from July to September and go to other places instead, probably farther out to sea.

I can probably assume now that the reader is satisfied of the existence of a yearly spawning cycle in herring. This is evidenced by the presence of a fattening period and by the figures reported above, quite independently of the assumption of two varieties. Therefore this section can be readily presupposed in the section on varietal differences.

6. Summary.

Migrations of herring in Kiel Bay, and their causes

What follows is the result of a scheduled study over six years. From the countless important and difficult questions posed for researchers by the biology of herring, the Commission selected a few and attempted to resolve them by considering even the most trivial details. In particular, no effort has been spared to study Kiel herring of all sizes in every season and in every part of the region. In this way, we have been able to create an adequate foundation for further research on herring, which is advancing into still unknown areas step by step.

Kiel Bay, broadly defined, is inhabited by two races differing in form and behavior: a spring or coastal form, and an autumn or ocean form, Var. B and A. The formal differences are chiefly in the external shape of the body, but partly also in inner organs. They are generally not major differences, but they are sufficient to be accurately recognized and described. The differences in behavior are mainly that the two races spawn in different seasons and in places with different conditions, and further, that the young herring pass through their larval stage in different locations and under dissimilar physical conditions. But the different behavior of the two races also causes their different forms. There are formal as well as behavioral intermediates between the two races; the intermediates, altogether, make up ca. 25-30 % of the total herring population.

Autumn herring (Var. A, Figure 1) are a minority, comprising approximately one-third of the total herring population or half of the total spring population. The most important formal characters of this variety are a slightly larger maximal size, greater numbers of keel scales and vertebrae, a shorter and lower tail, and more posterior dorsal and ventral fin locations. The adult spawns in the open water of Kiel Bay (exactly where, can not yet be determined) in October, November, and December, with an average salinity of 1.6- 1.7 % and with water temperatures declining rapidly from 12° to ca. 2° C.

During and after spawning, the autumn herring visit Eckernförde Bay and Kiel Bay, where they reach the innermost parts of the bays and mingle with the spring herring. Especially in spent individuals, the stomach and gut are full of copepods, showing that these fish are following only the feeding instinct. This behavior continues throughout the winter at least until March, and during this time the fish are caught regularly by fishermen. This is the fattening period; the development of the sex products is arrested until March or later, while enormous quantities of fat are stored in all organs. Such autumn herring are also always better-tasting than the much slimmer spring herring caught at the same time. In April and May, this behavior changes. While the spring herring now migrate to the Schlei to spawn, the autumn herring do not follow them-- or at best always only a few autumn herring follow them. However, the autumn herring too leave the inner parts of the bay, and avoid these areas all summer until about the middle of October. Where they stay at this time, while their sex products are gradually maturing, can not yet be determined with certainty, but it is highly probable that they wander farther out to sea. Incidentally, isolated autumn herring are also found in the bays.

Spring herring (Var. B, Figure 2) are characterized by a slightly smaller maximal size, smaller numbers of keel scales and vertebrae, a longer and higher tail, and more anterior dorsal and ventral fin locations. The adult spawns in April and May (in isolated cases, as early as the end of March or as late as the beginning of June), usually in the brackish water of the Schlei, with fewer numbers spawning in other shallow, brackish inlets such as the lagoon near Eckernförde and Dassow Lake, and sometimes the estuaries of small rivers like the Schwentine. The salinity of the water in the Schlei at this time is only 0.5 %, while temperatures are rising steadily from 2° to 20° C. In the salt water of the river estuaries, salinity is higher at this time and the temperature lower, but not as low as in the autumn. After spawning, the emaciated spring herring leave the Schlei and return to the salt water to fatten for the next three months. During this period (until the end of September or mid-October) they are almost as infrequent as the autumn herring in the inner parts of the bay, and they are encountered regularly only in the deepest portions, such as the Wittlingskuhle in Kiel Harbor. From October to March, they again visit the shallow inner parts of the bays while their sex products are ripening; then they form the great majority of what are known as Kiel and Eckernförde winter herring. Formerly, they sometimes used to return to the Schlei in autumn as well. Spring herring taste best and command the best prices in autumn, when their eggs and sperm are just starting to develop and most of the fat is still present.

The eggs of autumn spawners very probably require fourteen days from when they are deposited to hatch. The average length of freshly hatched larvae may be 7 mm. The larval stage is passed in salt water during the winter and spring. It lasts from five to seven months, so that it is completed in May to June. At that time, the young autumn herring have reached a total length of approximately 60 mm. Then, as fully developed herring, they mingle with the more numerous brood of Var. B, and can be found together with them throughout the year. Autumn herring probably are fully grown and ready for spawning in the last half of their second year, when they may measure slightly more than 200 mm in length.

The spring spawners deposit their eggs on rocks and aquatic plants[1] in the Schlei. The eggs need only six to twelve days to develop, and the average length of the freshly hatched larvae is only 6 mm. The larvae complete their development and attain the definitive herring form in just two or three months in the Schlei, i.e., in June to August. Then the young fish measure 40 to 50 mm. Some of them-- apparently a minority-- remain in the Schlei, and either leave at the beginning of winter or remain there an entire year, as is indicated by isolated herring with total lengths from 120 to 130 mm caught in the Schlei in June (cf. the long table). However, the majority of the winter brood leave the Schlei in July and August after attaining the definitive herring form, and migrate to salt water. Here their migration seems to depend very much on the weather, and especially on the current. For example, if Kiel has hot, sunny weather in August and September and the current is inbound, then the inner corners of the bay are full of myriads of young herring. They range from 50 to 100 mm long, so that they are partly spring brood from the same year, and partly autumn brood from the previous year, or spring herring with retarded growth. Usually also sprat of the same size are mingled with the young herring.

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[1] Annual reports IV to VI of the Commission, p. 26.

During the remaining months of the year, from October to June, young spring and autumn herring with lengths from 60 to 120 mm are found together, always in large numbers, in the inner parts of the bay. During the autumn and winter months, from October to early March, they apparently are always mingled with the adult fish; later in March and April, when the sexually mature fish migrate to the Schlei, the young herring separate and remain in salt water. This explains why more young herring (100- 140 mm long) are caught in Kiel Bay and especially in Eckernförde Bay in late March and April than in any other season, at a time when only very few large herring are still caught in salt water, and the fishing season in the Schlei is under way. The amount of young herring caught in the nets on one day is often so large that whole boatloads can not be utilized and must be thrown away. From March to May, these partially grown herring are mingled with sprat, which are now in their spring spawning season and measure ca. 110 to 140 mm in length.

After completing their first year of life, the young spring herring, with ca. 160-190 mm, join the fully grown, spent fish in the autumn of the following year, and spawn for the first time in the next spring, usually with a total length of ca. 200 mm. The smallest spring spawner with eggs ready for fertilization which I have encountered measured 189 mm. It seems to be the rule, at least in the Schlei, that the largest herring are the first to spawn, and the smallest spawn last.

As already mentioned, a small portion of spring herring spawn in river estuaries in April and May; hitherto, we have as little exact knowledge of the fate of this brood as we have for the offspring of those few fish which spawn in January and February. However, for various reasons which have already been discussed above, we can assume that this brood will be intermediate in form between autumn and spring herring larvae.

A review of the above outline is instructive in various ways.

As might have been expected *a priori*, the causes of the regular herring migrations are the feeding instinct and the reproductive instinct. For each race, we can distinguish three periods in each year: a spawning season, a fattening season, and a ripening season.[1]

In the first period, the spawning season, herring seek locations where conditions suit the natural requirements for the development of the eggs and the initial feeding of freshly hatched larvae. For spring herring, such conditions exist in April and May in brackish water; for autumn herring, in October and November in salt water. Undoubtedly the most important factor is that the water at the spawning site should be sufficiently aerated for the respiratory requirements of the eggs, or-- what amounts to the same-- that a sufficient flow of water should be constantly replaced. Also, food should be immediately available for the hatching larvae. Probably more exact research would reveal that the brackish water in the Schlei is never richer in copepods, water fleas, mussel embryos, etc. than in the months from May to July; whereas in the salt water of the bay, probably the greatest abundance of copepods and other food suitable for herring larvae occurs in the second half of the year, from August to November.

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[1] Probably these three seasons occur also in the case of other migrant fishes. Mackerels are very lean shortly before their spawning season in the spring, and very fat afterwards in the fall. According to BARFURTH, Rhine salmon are very lean just before spawning, but hasten quickly back to sea afterwards to fatten.

The second, or fattening period, of course, coincides with the larval stage of the new brood. Also, the needs of spawned out adults and young larvae are the same; both require abundant food, and will seek areas where it is available.

Hence it happens that spent autumn spawners are found in the same locations with young autumn larvae; the open sea, with its abundance of copepods, offers sufficient food for old and young fish alike. The situation is different for spring herring. The narrow area of the Schlei can probably supply adequate food for the young larvae, but not for the many adults, which are emaciated after spawning. Therefore the adults leave the Schlei to seek more productive feeding grounds. As already mentioned, the exact location can not be determined; at any rate, it is not in the surface strata of the bay, but at somewhat greater depths. Perhaps here also an exact investigation will reveal that the most plentiful supply of herring food occurs in the surface layers of the water in autumn and winter, but at greater depths in summer. It is also possible that adult herring choose a different type of food in summer than in winter-- instead of copepods, perhaps larger crustaceans, or the like.

The third period, during which the sex products mature, falls in winter and early spring for spring spawners, at a time when plentiful food is available particularly in the shallower parts of the bay. But for the autumn spawners, this period is in the summer, and it coincides with the fattening period of the spring spawners, so that probably both races will be found in the same area.

The migrations of the young brood must be governed exclusively by the drive for food. However, it is possible, and even probable that the direction of the currents, which bear the young herring along almost involuntarily, are an important factor in this connection. The power of masses of water in motion on these young creatures can be seen very clearly in the innermost corners of Kiel Harbor, where millions of herring are moving about in the water when the tide is rising, and when the tide has turned, they suddenly disappear.

Incidentally, it should also be noted that young herring from 20 to 80 mm may require a much more uniform diet than adults. With their small mouth, they can probably only seldom ingest such large prey as Mysis flexuosa, Gammarus locusta, Polynoe cirrata, etc. Adults can easily do this, and analyses of stomach contents[1] show that they do so more frequently than we might expect, without impairing their ability to trap very small copepods in their gill strainer. Perhaps this difference in the ability to ingest prey explains why numerous young herring are found in the surface strata during the summer months; they must seek the copepods, etc. which are still there, albeit in short supply; and that supply is just sufficient for the larvae, but not for the adult herring, so that the latter must resort to other food at greater depths.

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[1] Cf. MOEBIUS, Nahrung der Heringe [The food of herring], Annual reports IV-VI of the Commission, p. 173.

But that is enough speculation. In the future, regular new research will resolve to what extent the changing distribution of herring food in different places and seasons influences the migrations of these still enigmatic creatures.

Chapter Two

Herring outside of Kiel Bay

In Chapter One, my study of the herring in Kiel Bay reached certain conclusions. I can not hold out any prospect of similar results on the questions to be treated next. In Kiel Bay, I had the possibility of observing herring of all sizes in all seasons. But outside of this body of water, I could neither determine the spawning seasons by investigations on location, nor obtain sufficient samples of larvae and juvenile herring. My research was thus limited to examining approximately four hundred herring from various locations, which hardly suffices to establish a few general conjectures concerning the existence of different races in the North Sea and the Baltic. Nevertheless, I shall present this material in several tables, because it can serve as a basis for further research. It would be very desirable if our northern neighbors would accept the method which I have introduced and use it to analyze their extensive and valuable experience; this would undoubtedly be a meritorious undertaking, but one which, for obvious reasons, I can not fully execute. Therefore, as long as I can not perform investigations on location, I also can not discuss here the Norwegian and Swedish research on herring.

1. Herring of the western Baltic

Dr. MEYER's investigations concerning the spawning times of herring in the part of the Baltic extending from the Belts and the Sund to a line connecting Ystad with the eastern point of Rügen have shown that autumn herring and spring herring occur almost everywhere. The spring herring are more numerous, just as in Kiel Bay.

In Neustadt Bay, or Lü[illegible] Bay, the situation is exactly the same as in Kiel Bay; the brackish Dassow Lake is the spawning ground of spring herring, and I am convinced from inspection that it plays the same role as the Schlei. Also the spawning season, April and May, is the same.

It is not yet known whether spring herring spawn in brackish waters also at other locations in the area in question, but there is hardly any doubt that they spawn in salt water in various places, such as the Little Belt and Flensburg Bay, where Dr. MEYER reports[1] that fishermen regularly observe the herring spawning from small projecting tongues of land.

1. The only spring spawners in brackish water which I examined were three spawned out individuals in Dassow Lake listed in Table II. Although the examination was not completely adequate, these three herring resembled Var. B of Kiel Bay so closely that I do not hesitate to declare the

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[1] Annual reports IV-VI of the Commission, p. 232.

spring herring of Dassow and the Schlei as identical races in both form and behavior.

Table II.

a. Dassow Lake, June 1, 1875

Spring herring

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date

Totallänge. ①	Seitliche Kopflänge. ②	Formel ③ der Höhen, Längen und Kielschuppen				Ort. ④	Datum. ⑤	
233.0	c	1	3 a I	3 b III B	—III.	Dassow	1/6 75	VII
227.0	c	1	3 a I	2 b II B	—III.	„	„	„
215.0	c	2	2 b I	2 c III C	—II.	„	„	„

b. Greifswald Inlet, March, 1873

219.0	c	1	3 a I	2 c III C	—II.	Greifsw.	15/3 73
*218.0	c	1	3 a I	2 a II A	—	„	„
213.0	c	1	2 a II	2 b III B	—II.	„	„
210.0	c	1	3 a I	2 b III B	—III.	„	„

Note: Individuals marked with an asterisk exhibit form A, the others show form B.

Apparently the same applies to the four herring which I examined from Greifswald Inlet, but their spawning time can no longer be determined.

2. Among spring herring spawning in salt water, I examined more closely one local form-- Langeland spring herring. Table III lists sixteen herring in the process of spawning, which I obtained from a fisherman from Langeland, and which were caught in the open salt water off the coast of that island.

Table III. Langeland, Spring herring

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- sex and maturation stage 7- May

Totallänge mm ①	Seitliche Kopflänge. ②	Formel der Höhen, Längen und Kielschuppen. ③				Ort. ④	Datum. ⑤	Geschlecht und Reife. ⑥
249.0	c	1	1 b I	1 b II A	a II α	Langeland	26. Mai 78	♂ VI
*246.5	c	1	2 a I	2 c II A	b II β	„	⑦	♂ VI
245.0	b	1	1 b I	2 b II B	b II β	„	„	♀ VI
243.0	b	1	2 b I	1 b I B	b II β	„	„	♂ VI
242.5	c	1	—	2 a I B	b II —	„	„	♀ VI
236.5	c	1	2 b I	1 a II A	b II β	„	„	♂ VI—VII
235.5	b	1	2 b I	1 a o B	a II α	„	„	♀ VI
235.3	b	1	2 a I	2 o II B	— III —	„	„	♀ VI—VII
233.0	c	1	2 — I	2 b II A I	a II α	„	„	♂ VI
232.0	b	1	1 b I	1 b II A 1 c III	— II —	„	„	♀ VI
*228.5	c	1	3 a I	2 b II B	b II β	„	„	♂ VII
*221.5	c	1	1 a II	2 b III A	a II α	„	„	♀ VI
217.5	c	1	2 a I	2 b I B	a II α	„	„	♂ VI
*213.0	c	1	— o I	3 b III B	— II —	„	„	♀ II
212.0	b	1	—	2 a II A	— II —	„	„	♀ VI
*196.2	b	1	1 a I	3 b II A	b III γ	„	„	♀ VI

Note: Individuals marked with an asterisk belong to Var. B, others to Var. A.

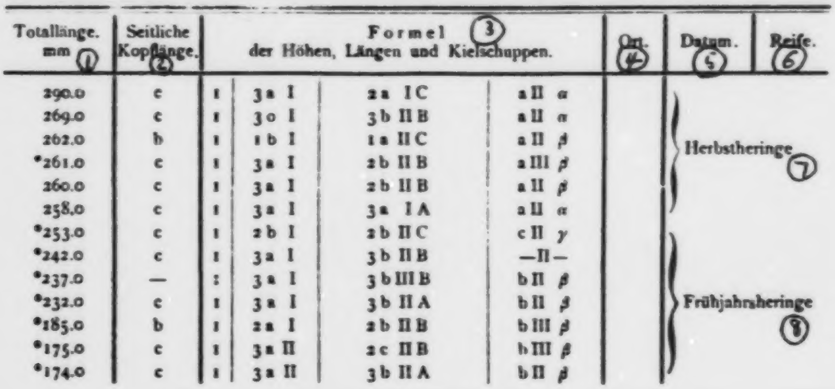
The result of this investigation is very remarkable. Of these sixteen herring, eleven belong to Var. A and only five to Var. B. The eleven spring herring from Langeland are exactly like the autumn herring of Kiel. At first glance, it would appear as if all of the conclusions which we drew from our investigation in the preceding section were overturned by this striking finding. At least it seems as if we can no longer designate forms A and B outside of Kiel Bay as autumn and spring herring.

However, a closer consideration of the results of the preceding section casts a different light on the Langeland spring herring, so that we recognize them merely as old acquaintances. The reader may recall that almost 19 % of all herring in Kiel Bay are spring spawners with body form A, and that spawning herring undoubtedly occur in the estuary of the Schwentine in April. Moreover, on the left half of the long table, among the larvae of form a, there are some young, fully grown individuals with a total length of 39-47 mm which were caught in Kiel Harbor in August. I already conjectured above that these remarkable creatures were the brood of spring herring spawning in salt water; my examination of the Langeland herring corroborates this opinion. Taking everything into consideration, I arrive at the conclusion that there are two kinds of spring herring in the western Baltic differing in form and behavior: a race which spawns in brackish water and has form B, and one spawning in salt water with form A. However, the latter does not seem to be identical with autumn herring of form A; at least, their development differs. The larvae of the spring herring spawning in salt water apparently attain the definitive herring form at a smaller length than those of autumn herring, although they do not assume a different form. The cause of this difference would be the higher temperature of the salt water in spring and summer as opposed to autumn and winter. This higher temperature simply has the effect of accelerating development; the relative body measurements remain the same in the spring larvae as in the autumn larvae, because the salinity and specific weight of the water differ only slightly compared to the brackish water of the Schlei or Dassow Lake.

Whether or not this hypothesis is correct will have to be resolved by more exact research later.

Table IV. Bundgarn herring from Korsör, October 1875

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage 7- autumn herring 8- spring herring



Totallänge. mm ①	Seitliche Kopflänge. ②	Formel ③ der Höhen, Längen und Kielschuppen.				Ort. ④	Datum. ⑤	Reife. ⑥
290.0	c	1	3a I	2a IC	aII α		Herbstheringe ⑦	
269.0	c	1	3o I	3b IIB	aII α			
262.0	b	1	1b I	1a IIC	aII β			
*261.0	c	1	3a I	2b IIB	aIII β			
260.0	c	1	3a I	2b IIB	aII β			
258.0	c	1	3a I	3a IA	aII α			
*253.0	c	1	2b I	2b IIC	cII γ		Frühjahrsheringe ⑧	
*242.0	c	1	3a I	3b IIB	—II—			
*237.0	—	1	3a I	3b IIIB	bII β			
*232.0	c	1	3a I	3b IIA	bII β			
*185.0	b	1	2a I	2b IIB	bIII β			
*175.0	c	1	3a II	2c IIB	bIII β			
*174.0	c	1	3a II	3b IIA	bII β			

Note: Individuals marked with an asterisk belong to form B, the rest to form A.

In conclusion, I should like to refer again very briefly to the 'Bundgarn' herring from Korsör at the outlet of the Great Belt, which were discussed already in Part One of my studies of herring varieties. Table IV lists thirteen herring caught in a ring net near Korsör in October, 1875. The first six herring listed actually do not belong here; they are undoubtedly only large Korsör autumn herring which are caught around the same time in the large drift nets and occasionally also wander into the ring nets. But the other seven fish, as is revealed by the appearance of their gonads, are spring spawners, or at least not autumn spawners. According to reliable reports from Korsör fishermen, this race is ripe for spawning in the spring, and is caught in the ring nets in far greater quantities then than in autumn. The fishermen could not state with certainty where the fish spawn; probably in shallow salt water.

The last seven herring in Table IV all belong to form B. If they are indeed spring spawners in salt water, we would have a further inconsistency. However, it is not important as long as numerous specimens of the race in question which are ripe for spawning have not been studied.

2. Herring of the eastern Baltic

It is well known that the western and eastern parts of the Baltic are quite different physically as well as biologically. It is therefore especially interesting to compare them also as regards their herring races; unfortunately, we can do this only very incompletely in the present paper.

If we compare data of various authors concerning herring varieties and spawning seasons in the eastern part of the Baltic, we will soon be certain that the situation here is no longer the same as in the western Baltic. Since the time of Linnaeus, very diverse authors have differentiated certain herring of the eastern Baltic from all other herring races as '*Strömling*'. These *Strömling* herring are supposedly characterized by a shorter length, a larger head, and behavioral differences.

The main spawning season in the eastern Baltic seems to be summer and autumn, not spring as in the western Baltic. According to ECKSTRÖM[1], there are two Strömling races in the shoals of Stockholm. The larger, more numerous form spawns from the end of May to the middle of June; the other, smaller and less numerous form in August and early September. According to WIDEGREEN[2], Strömling in the northernmost part of the Baltic already spawn in July, whereas those in the South do not spawn until October. According to KUPFFER[3], the herring near Pillau spawn at the outlet of the Frisches Haff in June. Finally, according to Dr. MEYER[4], the fishermen of Usedom, Hela, and Memel observed fish ripe for spawning in September and October. The most recent report is in BENECKE, Fische, Fischerei and Fischzucht in Ost- und Westpreussen ['Fishes, fisheries, and pisciculture in East and West Prussia'] (1880) vol. I,

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[1] ECKSTRÖM, Fische in den Schären von Morkö [Fishes in the shoals of Morkö], translated into German by Dr. F. C. H. CREPLIN, Berlin (1835), p. 207 ff.

[2] HJALMAR WIDEGREEN, Einige worte über die heringsartigen Fische [A few words concerning herring-like Fishes] Stockholm 1871.

[3] Annual reports of the Commission, years IV - VI, p. 177.

[4] op. cit., p. 230.

p. 170. According to this source, the main spawning season along the coasts mentioned is in May and June, while other shoals spawn on the northern coast of Samland in September.

Accordingly, most of the herring in the eastern Baltic should be designated as 'summer spawners'. Two different spawning seasons are present, but they are closer together than in the western Baltic. More exact research on spawning times and the numerical ratios of autumn and spring herring at different locations in the eastern Baltic would be of considerable interest. In combination with observations regarding temperatures and salinity, perhaps this research will help to explain the peculiar difference of form shown by most herring in the eastern Baltic compared to other races. That there is such a difference of form, is shown by the following data:

Key for Tables V - VIII.

1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage 7- February and March 1878 8- July 1876 9- predominantly autumn herring 'steril'- sterile [Fat content:] 'auss. viel'- exceptional 'mssg.', 'mäss.'- moderate 's. viel'- very high 's. wenig'- very low 'wenig'- low 'zieml.'- definitely high

Table V. Hela

Totallänge mm ①	Seitliche Kopflänge ②	Formel der Höhen, Längen und Kielschuppen ③				Ort ④	Datum ⑤	Reife ⑥	
281.5	b	1	3 b I	1 a II B	b II β	Hela.	Februar u. März 78.		steril
237.0	b	1	2 b I	2 b II B	a III β	"	" ⑦	♀	III
233.2	b	1	2 b I	2 b II B	b II β	"	"	♂	II s. viel
231.0	b	1	2 b I	2 b II B	a II α	"	"	♀	II wenig
*226.5	b	2	2 b I	2 b II B	b III γ	"	"	♂	V—VI
*221.7	c	1	2 b I	2 b III B	b II β	"	"	♀	V mssg.
*214.8	b	1	2 b II	3 b II B	b III β	"	"	♀	V

Table VI. Pillau. Autumn herring.

Totallänge mm ①	Seitliche Kopflänge. ②	Formel ③ der Höben, Längen und Kielschuppen.				Ort. ④	Datum. ⑤	Reife. ⑥
231.0	b	1	—	2 a II A	— II —	Königsbg.	Juli 76.	grösstentheils Herbstheringe. ⑨
228.0	b	1	1 b I	1 b II A	— II —	„	„ ⑧	
225.0	b	1	—	2 b II C III	— III —	„	„	
225.0	b	1	—	2 b II B	— II —	„	„	
223.0	b	1	—	3 b II A	— II —	„	„	
223.0	b	1	—	2 b III B	— II —	„	„	
222.0	b	1	—	2 b III B	— II —	„	„	
221.0	b	1	—	2 a II B	— III —	„	„	
219.0	b	1	—	2 b II B	—	„	„	
219.0	b	1	—	2 b II A	— II —	„	„	
216.0	b	2	—	2 a II B	— III —	„	„	
216.0	b	2	—	3 b II C	— II —	„	„	
215.0	b	1	—	3 b II B	— III —	„	„	
215.0	b	1	—	2 b III B	— III —	„	„	
213.0	b	1	—	2 o II A	— III —	„	„	
212.0	c	1	—	3 b II B	— II —	„	„	
212.0	b	1	—	2 b II B	— III —	„	„	
211.0	b	1	—	2 b II B	— II —	„	„	
211.0	—	1	—	3 b III B	— III —	„	„	
210.0	b	1	—	3 a III B	— III —	„	„	
210.0	b	1	—	2 a II B	— III —	„	„	
209.0	b	1	—	2 b II A	— III —	„	„	
208.0	b	1	—	3 b II B	— II —	„	„	
208.0	b	1	—	2 b II A	— II —	„	„	
207.0	b	1	—	3 b II B	— II —	„	„	
205.0	b	1	—	2 b II A	— II —	„	„	
203.0	b	1	2 b I	2 a II B	— III —	„	„	
202.0	b	1	—	2 a II B	— III —	„	„	
200.0	b	1	—	3 b II B	— I —	„	„	
200.0	b	1	—	3 b III C	— II —	„	„	
200.0	b	1	—	2 b II C	— III —	„	„	
200.0	b	2	—	2 b II B	— II —	„	„	
200.0	c	2	—	2 b III C	— II —	„	„	
195.0	b	1	3 b I	2 b II B	— III —	„	„	
195.0	c	1	2 a I	3 c III B	— III —	„	„	
195.0	b	1	—	2 b II B	— II —	„	„	
193.0	b	1	—	3 c II B	— III —	„	„	
192.0	b	1	—	3 b III B	— III —	„	„	
192.0	b	1	—	2 b III B	— III —	„	„	
191.0	b	1	—	2 a I B	— II —	„	„	
188.0	b	1	—	3 b III C	— III —	„	„	
188.0	b	2	—	2 b II C	— III —	„	„	
187.3	b	1	—	2 b II B	— II —	„	„	
185.0	b	1	—	2 b II B	— II —	„	„	
181.0	b	1	—	2 b II B	— II —	„	„	
180.0	b	1	—	4 c III A	— III —	„	„	
177.0	b	2	—	3 b III C	— II —	„	„	

Table VII. Kranz.

218.2	b	1	3 a I	2 a II B	a III β	Kranz	April 78	♂	II auss. viel.
215.5	b	1	2 b I	2 b II B	a III β	„	„	♀	V—VI s. wenig.
214.0	—	1	3 a I	1 b II B 2	o I o	„	„	?	II s. viel.
212.0	b	1	3 a I	2 b II B	a II α	„	„	♀	III s. viel.
208.5	b	1	2 b I	2 a II B	b II β	„	„	♀	V—VI wenig.
200.0	b	1	2 b I	1 b II B	a III β	„	„	♂	IV—V mäss.
200.0	b	1	3 a I	2 b II C	a II α	„	„	?	steril.
199.0	b	2	3 a I	2 b III C 3 C	a III β	„	„	?	II s. viel.
199.5	—	1	—	2 b III B	a II α	„	„	—	—
199.0	—	1	—	3 b II A	—	„	„	—	—
196.5	b	1	3 a I	2 a II B	a II α	„	„	♂	II s. viel.
196.0	b	2	2 a I	2 a II C	a III β	„	„	♀	III s. viel.
193.3	b	1	3 a I	2 b II B	b II β	„	„	—	—
192.5	b	1	3 a I	2 b II B	a II α	„	„	♂	II s. viel
191.2	b	1	3 a I	2 b III B	o II α	„	„	♀	V s. viel.
186.0	b	1	2 b II	[illegible]	[illegible]				

Table VIII. Memel.

Totallänge mm ①	Seitliche Kopflänge. ②	Formel ③ der Höhen, Längen und Kielschuppen.				Ort. ④	Datum. ⑤	Reife. ⑥	
240.5	b	1	2 b I	1 a II C	o II α	Memel	Nov. 77.	♀	II—III s. wenig.
237.5	b	1	3 a I	2 a II B	o II α	„	„	♀	VII ? mässig.
233.0	b	1	3 a I	2 a III B	a III β	„	„	♀	VII ? viel.
217.7	b	1	1 b I	1 a II B	b III β	„	„	♀	V s. viel.
215.0	b	2	2 b I	2 a II B	b III β	„	„	♂	V zieml.
213.2	b	1	3 b I	2 a III B 1 b C	b III β	„	„	♀	II s. viel.
207.0	b	1	2 b II	2 a I B II	b II β	„	„	♀	III—IV s. viel.
200.5	b	1	2 b II	2 b II B	b II β	„	„	♀	II s. viel.
196.0	b	1	2 b I	3 c III B	b II β	„	„	♂	II auss. viel.
185.0	b	1	2 b I	1 a II B	a II β	„	„	♀	III
183.7	b	1	2 b I	2 b II A	b II β	„	„	♀	II s. viel.
176.0	b	1	2 b II	2 a I B	b II β	„	„	♀	III s. viel.
174.6	a	1	2 b I	1 o I B II	b II β	„	„	♂	IV—V wenig.
174.5	b	1	2 b II	1 b I B	b III γ	„	„	♀	II—III s. viel.
172.6	—	1	2 c II	1 a II B	b III β	„	„	♀	III s. viel.
171.5	b	2	3 b I	2 b III B	c II γ	„	„	♀	III s. viel.
170.0	b	1	2 c I	1 a II A	b III γ	„	„	—	—
169.0	b	1	? b II	2 b II B 1	b II β	„	„	♂	II s. viel.
162.0	b	1	2 c II	2 a II A	b II β	„	„	♀	II—III s. viel.

b

Tables V - VIII list 7 herring from Hela, 47 from Pillau (mouth of the Frisches Haff), 19 from Memel (mouth of the Courland Lagoon), and 17 from Kranz (Samland). For those from Hela, Memel, and Kranz, the exact stage of the sex products was determined; those from Pillau were not determined as precisely, but most of them had very advanced eggs/ sperm, so that they should be regarded as autumn spawners.

Even a glance at these four tables will suffice to persuade the reader that these herring from the eastern Baltic have a different habit than the western herring.

a. First, the head is larger than in most western Baltic herring. Both the lateral head length and the height at the back of the head are greater; in both cases, level b is predominant.

b. Secondly, there are striking anomalies in fin locations, the location of the anus, and the number of keel scales. In these features, the eastern Baltic herring show a mixture of the characters of Var. A and Var. B, and can rightly be regarded as a third variety, C. This is clear from the following tables:

Key: Table 1- location of ventral fins Table 2- location of dorsal fin Table 3- location of anus Table 4- length of the base of the anal fin Table 5- number of keel scales between head and ventrals Table 6- total number of keel scales
1- Kiel autumn herring A 2- eastern Baltic herring C
3- Kiel spring herring B 4- number of individuals examined

1. Stellung der Bauchflossen.

Form.	Untersuchte Zahl	a	b	c	a : (b + c)
① Kieler Herbsthering A.	102	55	43	4	1 : 0.85
② Heringe der östlichen Ostsee C.	90	29	57	4	1 : 2.1
③ Kieler Frühjahrshering B .	259	33	195	31	1 : 7.0

2. Stellung der Rückenflosse.

Form.	Untersuchte Zahl	1	2	3	1 : (2 + 3)
Kieler Herbsthering A . .	99	20	73	6	1 : 3.9
Hering der östlichen Ostsee C	90	11	59	20	1 : 7.1
Kieler Frühjahrshering . .	254	14	177	63	1 : 17.0

3. Stellung des Afters.

Form.	Untersuchte Zahl.	I	II	III	I : (II + III)
Kieler Herbstsering A . .	84	32	48	4	1 : 1.6
Hering der östlichen Ostsee C	90	5	64	21	1 : 17.0
Kieler Frühjahrshering B .	219	26	175	18	1 : 7.4

4. Länge der Afterflossenbasis.

Form.	Untersuchte Zahl.	A	B	C	(A + B) : C
Kieler Herbsthering A . .	78	9	60	9	7.8 : 1
Heringe der östlichen Ostsee C	90	14	64	12	6.5 : 1
Kieler Frühjahrshering B .	204	21	154	29	6.0 : 1

5. Zahl der Kielschuppen zwischen Kopf- und Bauchflossen.

Form	Untersuchte Zahl	a	b	c	a : (b + c)
Kieler Herbsthering A . .	53	25	28	0	1 : 1.1
Hering der östlichen Ostsee C	42	20	21	1	1 : 1.1
Kieler Frühjahrshering B .	138	25	102	11	1 : 4.5

6. Summe aller Kielschuppen.

Form	Untersuchte Zahl	α	β	γ	α : (β + γ)
Kieler Herbsthering A . .	52	14	36	2	1 : 2.7
Hering der östlichen Ostsee C	42	10	28	4	1 : 3.2
Kieler Frühjahrshering B .	137	12	87	38	1 : 10.4

According to these figures, in the dorsal and ventral fin locations, the total number of keel scales, and the length of the anal fin, eastern Baltic herring fall between Kiel autumn and spring herring; specifically, they are more like the autumn herring in the first three characters, but closer to the spring herring in the last. Whereas in the location of the anus, they are equidistant from both Kiel races, since the anus is much farther forward, so that level III occurs much more frequently. In the number of keel scales between head and ventrals, form C is identical with

Kiel autumn herring. Thus, we have a peculiar, previously quite unknown combination of characters, expressed by the following formula: Var. C, (Fig. 3) b-1-2bI-1aIIIC-aIIIß, as opposed to Var. A, b-1-2bI-1aIA-aIα, and Var. B, c-1-3aI-3cIIIC-cIIIγ.

It should be emphasized once again that the numbers of keel scales are closely correlated with the location of the ventral fins and anus. Hence it is not surprising that the formula -aIII- combines a high number of keel scales before the ventral fin with a low number after the ventral.

Whether the actual 'Strömling' found off the Swedish Baltic coast, e.g., in the shoals of Stockholm and farther up in the Gulf of Bothnia, exhibits the same characters as my Var. C, will have to be determined by further research. Most likely, spring and autumn spawners will have different forms within the Baltic, as well. To resolve this, and all related questions, which undoubtedly are extremely important for a biological understanding of herring, what is most needed is knowledge of larval development. Incidentally, I shall have many further occasions below to refer to Var. C.

3. Herring of the Kattegat

I include here the large autumn herring from Korsör ('Korsör full herring' in Part One) which migrate between August and the end of November from the Kattegat through the Great Belt into the northern part of the western Baltic to spawn, and also the large autumn herring off the coast of Bohuslan. This remarkable race of herring disappeared almost completely in 1808 from its former fishing grounds, which it had visited in vast numbers for more than sixty years. Large catches were not taken again until December, 1877. Whole shiploads of these fish came from Gothenburg to Kiel, making it possible for me to study them in detail.

Table IX. Korsör. Autumn herring.

Key: 1- total length 2- head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage 7- all ripe or spent

Totallänge mm ①	Kopflänge ②	Formel ③ der Höhen, Längen und Kielschuppen				Ort ④	Datum ⑤	⑥ Reife
290.0	c	1	2 b I	2 a I B	a II β	Korsör	Octbr. 75	⑦ Durchweg laichreif resp. ausgelaicht.
290.0	c	1	3 a I	2 a I A	a II α	"	"	
285.0	c	1	2 a I	2 a I C	a II α	"	"	
280.0	c	1	2 b I	2 a I B	a II α	"	Septbr. 77	
280.0	c	1	2 a I	1 a I A	a --	"	"	
277.5	c	1	3 a I	2 a I B	b II β	"	Octbr. 75	
277.0	c	2	3 a I	3 a II B	b II β	"	"	
275.0	c	1	1 b I	2 a I B	b II β	"	"	
274.0	c	1	3 a I	3 b II A	a II β	"	"	
272.0	c	1	2 a I	2 b III B	a II α	"	"	
*271.0	c	1	1 b I	2 b III A	b III γ	"	"	
266.0	c	1	2 a I	2 a II B	a II β	"	"	
265.0	b	1	2 b I	2 a II B	a III β	"	"	
265.0	c	1	1 b I	3 a II B	a II β	"	"	
265.0	c	1	2 a I	2 a I B	a II α	"	"	
*265.0	c	1	2 a I	2 b II B	b II β	Korsör	Octbr. 75	Durchweg laichreif resp. ausgelaicht. Ventr. 1/9.
265.0	c	1	2 a I	2 a II B	b II β	"	"	
263.0	c	1	2 a I	1 b II B	c I β	"	"	
260.0	c	1	2 b I	1 a I B	a II α	"	Septbr. 77	
252.0	c	1	2 a I	2 a II B	— II —	"	Octbr. 75	
241.0	b	1	2 b I	1 a I B	b II β	"	"	
227.0	c	1	2 a I	2 a I B	a II β	"	Septbr. 77	
227.0	c	1	2 b I	2 a I A	b II β	"	"	
226.5	b	1	2 b I	2 a I B	a II α	"	"	
*224.0	—	1	3 a I	3 c III B	a II β	"	Octbr. 75	
220.0	c	1	2 a I	3 b II B	a II α	"	"	
*214.0	c	1	2 a I	2 b II B	b II β	"	"	
213.0	c	2	2 a I	2 a II C	a II β	"	"	
213.0	c	1	1 b II	2 a II B	o II α	"	"	

Note to Tables IX and X: Individuals marked with an asterisk have form B, the others have form A.

Table X. Bohuslan. Autumn herring.
Key: 1- total length 2- head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage
[fat content:] 'mässig'- moderate 's. viel'- very high 'wenig'- low 'zieml.'- definitely high

Totallänge mm ①	Kopflänge ②	Formel der Höhen, Längen uud Kielschuppen ③				Ort ④	Datum ⑤	Reife ⑥	
277.0	b	1	2 b I	1 a II B I	a II α	Göteborg	Jan. 78	♂	II zieml.
276.5	b	1	2 b II	1 a I B	o II α	„	„	♂	II zieml.
260.5	b	1	2 b II	2 b II B I	a II β	„	„	♀	II zieml.
259.5	c	1	2 b I	2 a I A	a II α	„	„	—	—
249.0	b	1	2 b II	1 b I A	b II β	„	„	♂	II s. viel.
244.5	b	2	1 b II	2 b III B I C	b II β	„	„	♀	VII—II s. viel.
235.5	b	1	2 b II	1 b II A	a IV γ	„	„	♀	II viel.
234.6	b	1	2 a II	1 b II A	b II β	„	„	♂	II s. viel.
231.0	—	1	2 b II	1 b II B	b o o	„	„	♂	II mässig.
223.0	c	1	-b II	2 c II B	a III β	„	„	♂	VII—II wenig.
196.0	b	1	2 a II	2 b II A	o I α	„	„		II viel.

Both types of herring, those from Korsör (Table IX) and those from Bohuslan (Table X), have the characters of Kiel autumn herring; however, as a rule, these characters are much more strongly expressed in the fish from the Kattegat than in their relatives in German waters, as can be seen from the following table:

Merkmal ⓐ	Herbsthering von ⓑ	
	Kiel	Kattegat
1. Seitliche Kopflänge b : c	1 : 2	1 : 2.5
2. Schwanzhöhe II : I	1 : 3.6	1 : 3.0
3. Rückenflosse 1 : (2 + 3)	1 : 3.9	1 : 3.0
4. Bauchflosse a : (b + c)	1 : 1.1	1 : 0.66
5. Afterstellung I : (II + III)	1 : 1.6	1 : 1.5
6. Afterflossenbasis (A + B) : C	7.4 : 1	19.0 : 1
7. Kielsch. zwisch. Kopf u. Bauchfl. a : (b + c)	1 : 0.85	1 : 0.60
8. Summe aller Kielsch. $\alpha : (\beta + \gamma)$	1 : 2.0	1 : 1.7

Key: a- character b- autumn herring from... c- Kiel
1- lateral head length 2- height of the tail 3- dorsal fin
4- ventral fin 5- location of anus 6- base of anal fin
7- keel scales between head and ventrals 8- total number of keel scales

In all measurements except head length, and in the number of keel scales, the levels characteristic of Var. A (II-1-a-I-[A+B]-a-α) occur more frequently in herring from the Kattegat than in those from Kiel. The fish from Bohuslan and Korsör differ in their lateral head length, and they are also differentiated by the fact that the dominant formulae are 1a and 1b among the former, and 2a among the latter. Probably both are very similar in their behavior. The herring from Bohuslan caught in January, 1878 were just spent, or else in their fattening period. Hence they must spawn in October and November, like Korsör herring. Although these fish are large and sometimes very fat, they are not highly valued, because their flesh is dry and soft, and they spoil easily. I could not study any spring herring from the Kattegat, although their existence has been definitely confirmed by the observations of Swedish researchers.

4. North Sea herring

1. The herring found in large numbers in August near Peterhead on the coast of Scotland are doubtless autumn spawners. Twenty specimens of this race are listed in Table XI: All had sex products nearly ripe, and would have spawned in September, or October at the latest. Eighteen of these twenty definitely have the character of Var. A, while two belong to form B. In the lateral head length, like the

autumn herring of Korsör, they tend more towards Kiel spring herring, with level c predominating.

Table XI. Peterhead. August. Autumn herring.

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage

Totallänge mm ①	Seitliche Kopflänge ②	Formel ③ der Höhen, Längen und Kielschuppen				Ort ④	Datum ⑤	⑥	
300.0	c	1	1 c I	1 a I B	II	Peterh.	August 72	♀	V. IV—V
280.0	c	1	1 c I	1 b II B	II	„	„	♀	„
*280.0	c	2	0 —	3 b II C	II	„	„		„
280.0	c	1	1 —	1 b I B	II	„	„		„
279.0	b	1	1 —	1 b II B	I	„	„		„
277.0	c	1	1 —	1 b II B	II	„	„		„
275.0	c	1	0 —	1 b II B	II	„	„		„
274.0	c	2	1 —	1 a I C	II	„	„		„
274.0	b	1	1 —	2 b II B	II	„	„		„
273.0	c	1	1 b II	2 a II A	II	„	„	♂	
272.0	b	1	1 —	2 a II B	III	„	„		
270.0	c	1	0 —	2 a I A	II	„	„		
267.0	c	1	1 —	2 a II B	II	„	„		
265.0	c	1	0 b II	2 a I A	II	„	„	♀	
265.0	b	1	0 —	1 b II A	II	„	„		
264.0	c	1	1 —	1 b II B	II	„	„		
257.0	b	1	0 —	1 a I B	II	„	„		
*254.0	c	1	1 —	2 b II B	II	„	„		
250.0	c	1	1 c II	1 a II A	II	„	„	♀	
285.0	c	1	1 —	1 a II B	—	„	„		

Note to Tables XI and XII: Individuals marked with an asterisk have form B, the rest have form A.

Table XII. Bergen. Large spring herring, 1876.

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage 7- spring, 1876

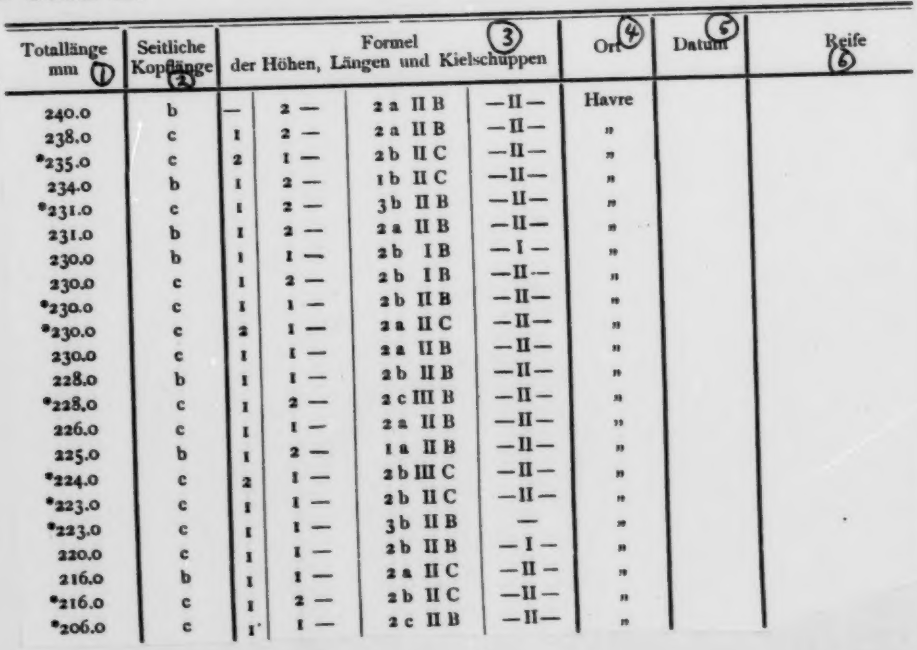
Totallänge mm ①	Seitliche Kopflänge ②	Formel der Höhen, Längen und Kielschuppen ③				Ort ④	Datum ⑤	Reife ⑥
337.0	b	1	3 —	1 a I B	— II —	Bergen	Frühj. 76.	V, VI, VII
333.0	c	1	2 —	2 a II B	—	„	„ ⑦	
*332.0	c	1	2 —	2 a II C	— III —	„	„	
*332.0	c	1	1 —	2 a III B	— II —	„	„	
327.0	b	2	2 —	1 b II C	— II —	„	„	
317.0	c	1	2 —	1 a I B	— II —	„	„	
314.0	c	1	3 —	2 a II B	— II —	„	„	
313.0	b	2	1 —	1 b II B	— II —	„	„	
310.0	c	1	1 —	1 b II B	— II —	„	„	
*309.0	c	2	2 —	2 a II C	— II —	„	„	
296.0	b	1	2 —	2 a II B	— II —	„	„	
280.0	b	1	2 —	2 a I B	— II —	„	„	
275.0	c	1	3 —	2 b I B	— II —	„	„	
274.0	b	1	3 -	2 a I A	— II —	„	„	
272.0	b	2	2 —	1 a I C	— II —	„	„	
*268.0	c	1	2 —	2 b II B	— I —	„	„	
268.0	b	1	3 —	2 b II B	—	„	„	
*260.0	c	2	2 —	2 b II B	— III —	„	„	
257.0	b	1	2 —	2 a I C	— II —	„	„	
255.0	b	2	2 —	2 b III B	— II —	„	„	
250.0	c	1	2 —	2 a II B	— II —	„	„	
*248.0	—	1	1 —	3 b II B	— II —	„	„	
*247.0	b	1	4 —	3 b II B	— I —	„	„	
247.0	c	1	3 —	2 b I B	— II —	„	„	
246.0	b	1	3 —	2 b III B	— II —	„	„	
244.0	b	1	3 —	2 a I A	— II —	„	„	
239.0	b	1	3 —	1 a II B	— II —	„	„	
*236.0	c	1	1 —	2 b II B	— III —	„	„	
*232.0	c	2	2 —	2 b III B	— II —	„	„	
125.0	b	2	3 —	2 c III B	—	„	„	
125.0	b	1	3 —	2 b III B	— II —	„	„	

2. Table XII lists 29 large Norwegian spring herring (Norwegian 'Vaarsild') caught in March or April, which the Commission obtained through the kindness of Mr. BOAS. Examination of the sex products revealed that these fish were either spent, spawning, or close to spawning. Two individuals with total lengths of 125 mm probably do not belong to the same race. Twenty out of 29 belong to form A or are intermediate between A and B. Nine have form B. Thus, Bergen spring herring is a very unusual race; it has the

same characters as the autumn herring of Kiel Bay and the Kattegat, but spawns in spring. However, the characters of form A, at least as far as we can judge from the individuals hitherto examined, seem to be less developed here than in the herring of the Kattegat and Peterhead. Therefore this race would best be classed with the Baltic spring herring spawning in salt water-- e.g., those from Langeland (Table III); indeed, they have not only the same form, but the same spawning time. The only major difference is that the Norwegian spring herring attain a greater maximal size, and in this respect they probably excel all other herring races.

XIII. Herring from the Channel (Havre de Grace)

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage
Note: Individuals marked with an asterisk have form B, the others form A.

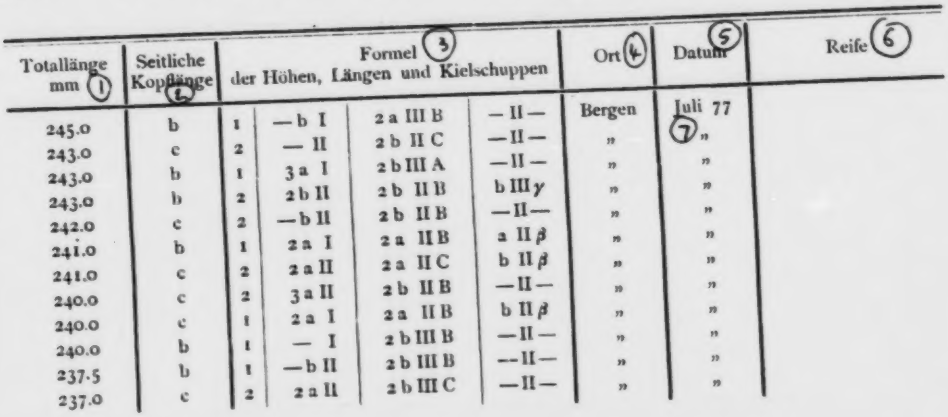


Totallänge mm ①	Seitliche Kopflänge ②	Formel der Höhen, Längen und Kielschuppen ③				Ort ④	Datum ⑤	Reife ⑥
240.0	b	—	2 —	2 a II B	—II—	Havre		
238.0	c	1	2 —	2 a II B	—II—	"		
*235.0	c	2	1 —	2 b II C	—II—	"		
234.0	b	1	2 —	1 b II C	—II—	"		
*231.0	c	1	2 —	3 b II B	—II—	"		
231.0	b	1	2 —	2 a II B	—II—	"		
230.0	b	1	1 —	2 b I B	—I—	"		
230.0	c	1	2 —	2 b I B	—II—	"		
*230.0	c	1	1 —	2 b II B	—II—	"		
*230.0	c	2	1 —	2 a II C	—II—	"		
230.0	c	1	1 —	2 a II B	—II—	"		
228.0	b	1	1 —	2 b II B	—II—	"		
*228.0	c	1	2 —	2 c III B	—II—	"		
226.0	c	1	1 —	2 a II B	—II—	"		
225.0	b	1	2 —	1 a II B	—II—	"		
*224.0	c	2	1 —	2 b III C	—II—	"		
*223.0	c	1	1 —	2 b II C	—II—	"		
*223.0	c	1	1 —	3 b II B	—	"		
220.0	c	1	1 —	2 b II B	—I—	"		
216.0	b	1	1 —	2 a II C	—II—	"		
*216.0	c	1	2 —	2 b II C	—II—	"		
*206.0	c	1	1 —	2 c II B	—II—	"		

3. Table XIII shows the formulae of 22 herring from the Channel, caught in the vicinity of Havre de Grace. Since I do not know when they were caught, I can not determine whether they are spring or autumn spawners. Their racial character is mixed; ten have form B, twelve have form A or are intermediate. No conclusions can be drawn from examining these fish.

Table XIV. White herring from Bergen.

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- maturation stage 7- July 1877



Totallänge mm ①	Seitliche Kopflänge ②	Formel ③ der Höhen, Längen und Kielschuppen				Ort ④	Datum ⑤	Reife ⑥
245.0	b	1	— b I	2 a III B	— II —	Bergen	Juli 77	
243.0	c	2	— II	2 b II C	— II —	„	⑦ „	
243.0	b	1	3 a I	2 b III A	— II —	„	„	
243.0	b	2	2 b II	2 b II B	b III γ	„	„	
242.0	c	2	— b II	2 b II B	— II —	„	„	
241.0	b	1	2 a I	2 a II B	a II β	„	„	
241.0	c	2	2 a II	2 a II C	b II β	„	„	
240.0	c	2	3 a II	2 b II B	— II —	„	„	
240.0	c	1	2 a I	2 a II B	b II β	„	„	
240.0	b	1	— I	2 b III B	— II —	„	„	
237.5	b	1	— b II	2 b III B	— II —	„	„	
237.0	c	2	2 a II	2 b III C	— II —	„	„	

Totallänge mm ①	Seitliche Kopflänge	Formel ③ der Höhen, Längen und Kielschuppen				Ort ④	Datum ⑤	Reife ⑥
237.0	b ②	2	2 a II	3 b III C	— II —	Bergen	Juli 27	
237.0	b	2	1 b II	2 b III C	b II β		„ ⑦	
237.0	c	1	3 a I	2 b II A	— II —	„	„	
236.0	c	2	— II	2 b III B	— II —	„	„	
235.0	c	2	— b II	2 b III B	— II —	„	„	
234.0	c	2	2 a I	2 b III A	o II α	„	„	
234.0	b	2	2 a II	2 b III C	b II β	„	„	
234.0	b	2	2 b II	2 b III C	a II β	„	„	
234.0	c	2	2 b II	2 b IV B	— II —	„	„	
234.0	b	2	3 a II	2 a III B	— II —	„	„	
233.0	c	2	2 a II	2 b II C	— II —	„	„	
233.0	c	2	2 b II	1 a III B	b III β	„	„	
232.0	b	2	2 b II	2 a II B	— II —	„	„	
232.0	b	2	2 a II	2 a II B	— III —	„	„	
232.0	b	2	2 a I	1 a II B	b II β	„	„	
232.0	b	2	2 b II	2 a II B	b II β	„	„	
232.0	b	2	2 b II	2 b II B	b II β	„	„	
232.0	c	1	2 a II	2 b III B	b II β	„	„	
232.0	b	1	— a II	1 b III B	— II —	„	„	
231.5	b	1	2 b II	2 a II B	b II β	„	„	
231.0	c	2	— I	2 b III B	— II —	„	„	
231.0	c	1	2 b II	2 b III B	b II β	„	„	
231.0	c	1	3 a II	2 b II B	b III β	„	„	
231.0	c	1	— a II	2 b III B	— II —	„	„	
231.0	c	2	2 a I	1 b II B	— II —	„	„	
230.0	b	2	3 b II	1 b II B	b II β	„	„	
230.0	b	2	3 a I	2 b III B	b III γ	„	„	
229.0	b	1	2 b II	2 b III B	b II β	„	„	
229.0	c	2	2 b II	2 b III B	— II β	„	„	
229.0	b	2	2 c II	2 b III B	b II β	„	„	
229.0	c	2	2 b II	2 b III B	c II γ	„	„	
229.0	b	2	2 b II	2 a II B	b II β	„	„	
229.0	b	2	2 b II	2 b II B	b II β	„	„	
229.0	b	2	2 b I	2 b II B	— II —	„	„	
228.0	b	2	3 a II	2 b III B	— II —	„	„	
228.0	b	2	2 b II	2 a II B	b II β	„	„	
228.0	c	2	2 b II	2 b III B	— II —	„	„	
228.0	b	1	2 b II	2 b III A	b II β	„	„	
227.0	b	1	— b II	1 a II B	— II —	„	„	
227.0	c	2	— b II	1 a III C	— III —	„	„	
226.0	b	1	1 b II	2 b III B	b II β	„	„	
226.0	b	2	2 b II	2 b III C	a III β	„	„	
226.0	b	1	1 b II	2 a II B	b III β	„	„	
225.0	b	2	2 b II	2 a II B	— II —	„	„	
225.0	b	2	2 b II	1 b II C	b II β	„	„	
225.0	b	1	2 b II	1 b II C	— II —	„	„	
225.0	b	1	2 b II	2 b III B	b II β	„	„	
224.0	b	1	2 b II	2 c III C	— II —	„	„	
223.0	b	2	2 b II	2 b II B	b II β	„	„	
223.0	b	2	2 b II	1 a II C	b III β	„	„	
223.0	b	2	2 b II	1 a II C	a III β	„	„	
222.0	b	2	3 a II	2 a II B	— II —	„	„	
222.0	b	2	2 b II	1 b III A	— III —	„	„	
222.0	b	2	— b I	2 a III B	— III —	„	„	
221.0	b	2	1 b II	2 b III B	a II α	„	„	
221.0	c	2	2 b II	1 a III B	a III β	„	„	
219.0	b	2	— b II	2 a III B	— II —	„	„	
219.0	b	2	— II	2 a II B	— II —	„	„	
219.0	b	2	3 a II	1 b III B	— II —	„	„	
219.0	b	2	2 c I	2 c III B	c III γ	„	„	
215.0	b	2	2 a I	1 a II B	b II β	„	„	
215.0	b	2	2 b II	1 a II C	b II β	„	„	
215.0	b	1	2 b II	2 b III B	b III β	„	„	
213.0	b	2	— b I	2 a II B	— II —	„	„	
212.0	b	1	2 b II	1 b III B	b II β	„	„	

Totallänge mm ①	Seitliche Kopflänge ②	Formel ③ der Höhen, Längen und Kielschuppen				Ort ④	Datum ⑤	Reife ⑥
211.0	b	2	2 b II	2 b III A	b II β	Bergen	Juli 77 ⑦	
207.0	b	1	2 b II	1 b III B	a II β	„	„	
193.3	b	2	— II	2 a III C	a II β	„	„	
191.0	b	2	2 b II	2 b III B	b II β	„	„	
186.0	—	1	2 b I	2 b III A	b II β	„	„	
174.0	—	1	3 a II	2 b I A	b II β	„	„	
166.0	b	2	3 a II	1 b III B	b II β	„	„	
164.0	b	1	3 a II	3 b III B	b II β	„	„	
163.0	b	2	3 b II	1 o II B	—	„	„	
162.0	b	1	3 a II	2 a III B	b II β	„	„	
161.0	b	2	3 b II	2 b III B	b II β	„	„	
159.0	b	1	3 a II	2 b III B	b II β	„	„	
159.0	b	2	— II	2 b — B	— II β	„	„	
156.2	b	1	3 a I	1 a II A	a III β	„	„	
156.0	b	2	3 a II	2 a III B	a II β	„	„	
155.2	b	2	3 a II	2 a III B	b II β	„	„	
154.5	b	1	3 a II	2 b III B	a II β	„	„	
153.6	b	1	3 b II	2 a II B	a II β	„	„	
151.4	b	2	3 b II	2 b III C	b II β	„	„	
151.2	b	1	3 b II	1 a II B	— III —	„	„	
151.0	b	1	2 b II	2 b III A	— II —	„	„	
150.0	b	2	3 a II	2 b III B	a II α	„	„	
137.4	a	1	—	2 a II B	c II γ	„	„	

4. Table XIV lists detailed findings for 100 herring with total lengths from 137 to 245 mm which Mr. BOAS sent from Bergen in August, 1877. These are the true 'Matjes-Hering' [white herring]. The sex products were at stage I or II, and every one of these fish was exceptionally fat. I could not decide whether they were autumn or spring spawners; therefore I shall have to be content to discuss in some more detail the interesting formal peculiarities of this race. An attentive survey of Table XIV reveals immediately that these fish resemble neither the Norwegian spring herring in Table XII nor the fish from Peterhead, from the Kattegat, or from Kiel. But they correspond quite strikingly with the eastern Baltic Var. C described above, with racial features expressed by the formula b-1-2bI-1aIIIC-aIIIß. Both

groups exhibit the same remarkable combination of variation levels which occurs in all other races only as a rare exception: an extremely anterior location of the anus together with extremely posterior dorsal and ventral fins, and, just as unusually, a high number of keel scales between head and ventrals with a very low number between the ventrals and the anus. In fact, the peculiarities of form C are even more distinctly manifested in Bergen white herring than in the eastern Baltic, as is shown particularly by the frequent incidence of level III for the location of the anus. The incidence of level III relative to levels (I+II) is as follows:

Peterhead autumn herring	0: -
Kiel autumn herring	1: 20.0
Kattegat autumn herring	1: 11.0
Kiel spring herring	1: 11.0
Bergen spring herring	1: 8.0
eastern Baltic herring	1: 3.3
Bergen white herring	1: 0.7

Thus, the 100 herring on Table XIV are the only race which we have investigated so far in which variation level III for the location of the anus occurs more frequently than levels I and II combined; i.e., they are the herring most closely approximating the related species _Cl. sprattus_ in this character.

This tendency to resemble sprat is manifested even more strikingly in another character, viz., the ratio of the length of the anal fin to the length of the dorsal. It is one of the characteristic differences between _Clupea_ *harengus* and *Clupea sprattus*[1] that in the former, the base of the dorsal fin is longer than the anal, while in the latter it is shorter. However, there are exceptions to the rule in both species. In the third column of my tables, the number 1 indicates that the base of the dorsal is longer than the base of the anal, while the number 2 indicates that the base of the dorsal is equal to or shorter than the base of the anal. Thus, 1 is characteristic for herring, and 2 for sprat (cf. Table XIX). Now, also in Bergen white herring, level 2 occurs more frequently than in any other form-- in fact, even more frequently than level 1.

A survey of the different local forms which we have investigated shows that the relative occurrence of level 1 in proportion to level 2 is as follows:

Kiel	16.4: 1
Kattegat	12.0: 1
Peterhead	9.0: 1
eastern Baltic	8.1: 1
Bergen spring herring	3.1: 1
Bergen white herring	0.5: 1

5. Herring of the Lower Elbe

Every year, from October to December, young herring with total lengths of 130 to 180 mm are caught in the Elbe between Hamburg and the mouth of the river, together with smelt (*Osmerus eperlanus*) and a peculiar variety of

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[1] Cf. Part One, p. 56 and 57.

Table XV. Elbe R. near Hamburg

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date

Note: Individuals marked with an asterisk have form B, the others form A.

Totallänge mm ①	Seitliche Kopflänge ②	Formel ③ der Höhen, Längen und Kielschuppen				Ort ④	Datum ⑤
181.5	b	1	1 b II	1 b II B	a II α	Elbe	Novbr. 77
173.7	b	1	2 b II	2 b IV B	a II α	„	„
*168.0	b	1	2 b III	2 b II A	b II β	„	„
166.6	b	1	1 b II	2 b II B	a II α	„	„
*166.1	b	1	1 b II	3 b II B	b II β	„	„
161.0	b	2	2 b —	2 b III C	b II β	„	„
160.8	b	1	1 c III	2 a II B	b II β	„	„
*160.5	b	1	1 c II	2 c III B	b II β	„	„
159.5	b	1	2 b II	2 b II B	b I β	„	„
159.5	b	1	1 c II	2 a II B	b II β	„	„
158.6	b	1	1 c II	1 b II B	a II α	„	„
*158.2	b	2	2 b II	2 b II C	— II —	„	„
158.1	b	1	1 b II	2 b II B	b II β	„	„
157.8	b	1	1 b II	2 b II B	b II β	„	„
157.7	b	1	1 c II	1 c II B	a I α	„	„
*156.5	b	1	1 c III	2 b III B	a II β	„	„
*155.8	b	1	1 b II	2 c III B	b II β	„	„
155.5	b	1	2 b II	3 b II A	b I α	„	„
*155.0	b	1	2 b II	1 b III C	b II β	„	„
154.5	b	1	1 c II	3 b II B	a II β	„	„
154.5	b	1	1 b II	2 b II A a I	b — I o	„	$K_1 = 20$
153.7	b	1	1 c II	3 b II B	b II β	„	„
153.5	b	1	2 b II	2 a II B	a II β	„	„
152.5	—	1	1 c II	2 b II B	b II β	„	„
152.5	b	1	2 b II	1 b II A	c I β	„	„
152.3	b	1	2 b I	2 b III B	a II β	„	„
*152.0	b	1	2 b III	2 b II B	c II β	„	„
151.0	b	1	1 b II	2 b II A	— II —	„	„
*150.0	b	2	2 b II	2 b II C	c III γ	„	„
149.7	b	1	1 c II	2 b II B	b II β	„	„
148.8	b	1	0 b II	1 b II B	— II —	„	„
148.2	—	1	2 c II	1 b II B	— II —	„	„
147.8	b	1	1 c II	2 b II B	— II —	„	„
*147.6	b	1	0 b III	2 b II B	b II β	„	„
147.0	b	1	1 c II	3 b II B	a II β	„	„
142.7	b	2	2 b II	2 a III B	b II β	„	„
137.8	b	2	2 b II	2 b II C	a II α	„	„
136.6	b	1	2 b II	1 a II B	b II β	„	„

sprat which I shall describe later. Since whole carloads of these Elbe sprat and herring are conveyed to Kiel for smoking, and these animals appear strikingly different from the Kiel fish, I examined a number of them and I have compiled my findings in Table XV. The sex products of these fish were always at stage I. The most striking peculiarity of the Elbe herring (Figure 11) is their very impressive body height. The height measurements at the back of the head and the origin of the caudal fin, as well as the maximal height are so great that at first glance, we have the impression that these are not herring, but sprat. Height formulae such as 1bIII and even 1cIII, which are otherwise found only in sprat, and in none of the herring races, are not infrequent; and these levels are diametrically opposite to the dominant formulae among Kiel herring, 3bI and 3aI. Also in other respects, the Elbe herring tend much more towards Var. A than Var. B. Only ten out of 38 individuals belonged to Var. B; the others had form A or were intermediate. Among other races which have been described, the fish most similar to these were the spring herring from Langeland and Bergen spawning in salt water.

Small herring from river estuaries and bays were already mentioned by YARREL in the second volume of his 'History of British fishes' in 1836. One form, the English 'Whitebait', described by YARREL as Clupea alba, is caught in very large quantities from April to the end of September in fixed nets facing upstream in the Thames, and is regarded as a delicacy. These are probably young herring which occasionally visit the river estuaries; the description given by the author does not contain any further information relevant for our purpose. But the other form, described by YARREL as Clupea Leachii, is strikingly similar to the small herring from the Elbe. As can already be seen from YARREL's illustration, it has a very striking body height and, as the English author explicitly mentions, the dorsal fin is located farther back than in most herring, so that it would probably rank, with Elbe herring, at variation levels 1 and 2. These small herring are observed in various inlets and estuaries, and YARREL observed them with well developed eggs in January.

6. Icelandic herring

Table XVI. Young Icelandic herring

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- remarks

Totallänge mm ①	Seitliche Kopflänge ②	Formel der Höhen, Längen und Kielschuppen ③				Ort ④	Datum ⑤	Bemerkungen ⑥
51.2	a	1	— o l	1 a III A	—	Island	1877	
54.3	a	1	— a l	1 a III C	—	„	„	
55.0	a	1	— a l	1 a II B	—	„	„	
57.5	a	1	— o o	1 b III C	—	„	„	
59.2	a	1	— b l	1 a II B	b III γ	„	„	
59.5	a	1	— a l	2 a III C	—III—	„	„	
59.7	a	—	— a l	1 b II B	—	„	„	
59.0	a	1	— a l	1 o II C	a III β	„	„	
61.0	a	1	— a l	1 b III B	—	„	„	
61.2	a	1	3 b II	2 a III C	a — —	„	„	
62.5	—	—	— a l	2 b III B	—	„	„	
63.0	a	1	— b l	1 a III B	a III β	„	„	
63.0	a	1	— a l	1 a II B	—II—	„	„	
64.2	a	1	4 a l	1 a III B	—	„	„	
67.0	a	1	3 b l	1 b III B	a II β	„	„	

By a fortunate coincidence, I obtained a small number of young herring in 1877 which had been caught off the Icelandic coast in the vicinity of Reykjavik. Fifteen adequately well preserved specimens from this collection are described in Table XVI. They measure 51-67 mm total length and are all, without exception, fully developed herring. If we compare these Icelandic herring with same-sized fish of both races found in Kiel Bay, we find that they resemble neither the autumn herring nor the spring herring. The lateral head length is larger (only variation level a occurs) and the height at the back of the head and at the beginning of the tail is smaller, so that these fish have a very slender shape. In fin locations, the location of the anus, the length of the anal fin, and numbers of keel scales, they are stikingly similar to form C, which we have encountered once in the eastern Baltic herring and again in the Bergen white herring. The typical formula -aIII-, and the adjacent levels -bIII- and -0II-, together cover eleven of the fifteen individuals, or more than 70 % of the total sample.

The occurrence of this remarkable form in three such widely separated parts of the European waters-- near Iceland, Bergen, and the Bay of Danzig-- is certainly peculiar and enigmatic. Perhaps it is connected with the fact that according to the findings of many researchers, the larger, eastern half of the Baltic exhibits very close links--

including very similar fauna-- with the White Sea, the Arctic Ocean, and other arctic waters. It is certain that the Gulf of Finland was once connected with the Arctic Ocean and was colonized by species from that body of water. At that time, the western Baltic was most likely separate from the eastern half and connected through Skaggerak, Kattegat, Sund and Belts with the North Sea and parts of the Atlantic Ocean farther south. At least, the present fauna of the western Baltic is certainly just as closely related to the ocean fauna off the French coast, and even to the Mediterranean fauna, as the eastern Baltic fauna is to that of the Arctic Ocean. But however that may be, I have no doubt that in all three areas where form C is observed today, it results from similar environmental conditions, and specifically from those conditions which affect the herring brood during the larval stage.

7. Summary

However limited and uncertain the results of this second chapter of our study may be, they still include some important findings.

1. Every local form of herring inhabiting an area of at least a certain size has its own character.

Thus, herring in the southeastern part of the Baltic (from Hela to Memel) are differentiated from all other races by the fact that they have the smallest number of keel scales between the ventrals and the anus. The white herring of Bergen are characterized by their close resemblance to sprat in the length of the anal fin; Bergen spring herring, by their very large size; Elbe herring by their unusual height, etc. Using formulae and listing the herring on tables is an excellent way of revealing the specific character of each and every local form. This again demonstrates that herring do not undertake long-distance migrations, but spend their entire lives within a narrow area. It is the physical and biocoenotic[1] conditions of these home ranges that determine the particular racial character of herring there.

2. While even the sixteen local forms which I have investigated exhibit manifold differences, they can still all be readily grouped into three varieties:

Group I. Var. A (Fig. 1)
Formula: b-1-bI-1aIA-aIα.

1. Peterhead (Scotland) autumn herring
2. autumn herring off the coast of Bohuslan (Kattegat)
3. Korsör autumn herring (Kattegat, Great Belt)
4. Kiel autumn herring
5. Bergen spring herring }
6. Langeland spring herring } spawning in salt water
7. Kiel spring herring }
8. Elbe herring

Group II. Var. B. (Fig. 2)
Formula: c-1-aII-3cIIIC-cIIIγ

1. Kiel spring herring } spawning in
2. Dassow spring herring} brackish water

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[1] I have adopted here a good term coined by MÖBIUS to describe the interdependence of all the organisms in an area.

Group III. Var. C. (Fig. 3)
Formula: b-1(2)-bI-1aIIIC-aIII.β

1. (autumn?) herring of the southeastern part of the Baltic ('Strömling'?)
2. Bergen white herring
3. Icelandic herring

Translations of the formulae for Var. A, B, and C into verbal descriptions of the three herring varieties which I differentiate, together with the species descriptions of *Clupea harengus* and *Clupea sprattus* may be found in Appendix I at the end of this treatise.

Chapter Three

Sprat (Clupea sprattus L.)

Table XVII. Sprat from Kiel Bay

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- remarks 7 and 8- See explanatory note 2 on p. 188 of the translation. 9- May 10- March 11- June 12- keel scales

Totallänge mm ①	Seitliche Kopflänge ②	③ Formel der Höhen, Längen und Kielschuppen		Datum ④	Ort ⑤	Bemerkungen. ⑥		
*23.5	f	8 —	—2d oB	25. Oct. 77	Kiel	V. embryon.		D. 17 A. 18
*24.0	f	8 —1	—3c o—	„	„	V. i. d. Bildg.		D. 16 A. 17
*24.5	d	7 —	—2d o—	„	„	V. 5	—⑦	D. 16 A. 15
**25.0	c	5 —	ob ll—	12. Aug. 76	„		—	— A. 17
*25.5	e	7 — o	—2d oA	25. Oct. 77	„	V. i. d. Bildg.		— A. 17
*25.8	e	7 — o	—2e o—	„	„	V. 3—4		D. 18 A. 18
*27.0	d	7 — l	—2c lB	„	„	V. entwick⑧		D. 18 A. 18
**27.0	b	6	—1c lll—	12. Aug. 76	„		—	— A. 19
*27.3	—	7 — o	—1d l—	25. Oct. 77	„	V. 4—5		D. 17 A. 18
*28.3	c	6 — l	—1d ll—	„	„	V. 7		D. 18 A. 20
*29.0	d	6 —	—2c l—	„	„	V. 7		D. 18 A. 17
**29.0	c	5 —	oc ll—	12. Aug. 76	„		—	— A. 18
*30.0	d	6 — l	—2c llD	25. Oct. 77	„		—	—
*30.0	—	—	od lB	27. Nov. 77	„	V. 7	—	— A. 17
*30.5	d	6 —	—1d o—	4. Dec. 77	„	V. 7	—	D. 18 A. 19
*31.0	b	6 — ll	—1e lll—	25. Oct. 77	„	V. 7	—	D. 18 A. 20
**31.0	c	6 —	—1d ll—	12. Aug. 76	Kiel	V. 7	—	D. 17 A. 19
**31.3	c	6 —	—1c ll—	„	„	V. 7	—	D. 17 A. 19
**31.4	c	6 —	—1c l—	„	„	V. 7	—	—
**31.5	c	6 —	oc ll—	„	„	V. 7		D. 18 A. 20
*32.0	d	6 — l	—1e llD	25. Oct. 77	„	V. 6—7		D. 18 A. 19
**32.3	c	6 —	oc ll—	12. Aug. 76	„	V. 7	—	D. 18 A. 19
**32.3	c	6 —	—1c l—	„	„		—	D. 16 —
*32.4	d	6 —	—2c llA	4. Dec. 77	„	V. 7	—	D. 18 A. 16
**32.6	c	6 —	od lll—	12. Aug. 76	„	V. 7	—	D. 18 A. 19
**33.0	b	4 — l	2c lVD	„	„	V. 7		A. 19
**33.4	c	6 —	1d lll—	„	„		—	—
**33.5	c	5 —	oc ll—	„	„		—	D. 18 —
*33.5	c	5 — l	—1c lllD	25. Oct. 77	„	V. 7	—	A. 17
**34.5	c	5 —	oc lllC	12. Aug. 76	„	V. 7	—	A. 18

42.4	c		4 — II	2 c IV E		12. Aug. 76	Kiel	V. 7 — A. 19
63.0	b	2	3 b III	2 b III E	e III ε	16. Sept. 75	Eckernförde	
59.0	b	2	3 b III	2 c IV C	f III ε	„	„	
65.0	b	2	3 a III	2 e V F	e IV ε	„	„	
66.0	b	2	2 b II	2 d IV E	e IV ε	„	„	
73.0	c	2	2 b II	2 c IV E	— IV —	13. Oct. 74	Kiel	
78.0	b	2	2 b III	1 c V E	— IV —	13. Oct. 75	„	
80.0	c	2	2 b III	2 c IV E	— III —	„	„	
79.5	b	1	3 a II	1 d IV C	e III ♂	⑨ Mai 76	Eckernförde	
83.0	c	2	3 b II	2 d IV E	d IV ε	„	„	
83.6	c	2	2 a II	2 c IV D	e IV ε	„	„	
84.0	b	2	3 a II	2 b III D	d IV ε	Mai 77	„	
94.5	c	2	2 b III	2 c III D	e III ♂	Mai 76	„	
95.0	c	2	2 a II	2 c III D	e IV ε	Mai 77	„	
95.5	c	2	3 a II	2 c IV D	e IV ε	„	„	
97.5	c	2	3 a II	1 d IV C	e IV ε	„	„	
97.5	b	2	2 b II	1 b III E	— IV —	Oct. 72	Kiel	
98.0	b	2	2 b II	2 c IV E	— IV —	„	„	
97.0	c	2	2 b II	1 d IV D	e III ε	Mai 76	Eckernförde	
99.0	c	2	2 b II	2 c IV D	e IV ε	„	„	
100.0	c	1	1 b III	1 c III D	e III ♂	Dec. 75	„	
101.0	c	2	2 b II	1 c IV D	— IV —	Oct. 72	Kiel	
104.0	c	2	2 a II	1 d IV E	— III —	Mai 76	Eckernförde	
110.0	c	2	2 a III	2 c III D	e IV ε	„	„	
112.6	c	2	2 a I	1 c III C	e III ε	Mai 77	„	
112.8	c	2	2 a II	1 c III D	e IV ε	„	„	
114.0	b	2	2 b II	1 c IV D	e IV ε	„	„	
117.5	c	2	2 a II	1 c III D	d III ♂	„	„	23 + 12 = 35 Kielschuppen
118.3	c	1	2 b II	2 c III C	d IV ♂	„	„	⑫
119.0	c	2	2 b II	1 c IV E	e IV ε	⑩ März 76	Kiel	
119.2	c	2	1 b II	1 c III D	e III ε	Oct. 76	Eckernförde	
119.8	c	2	2 b II	2 c IV D	e IV ε	Mai 77	„	
122.0	c	2	2 b III	1 d V C	e IV ε	März 77	„	
126.0	c	2	2 b II	1 c III D	e III ε	Mai 76	„	
128.0	c	2	2 b II	1 c III C	— III —	⑪ Juni 75	Kiel	
128.0	—	—	—	1 c III D	e IV ε	9. April 78	„	♀ VI-VII ?
128.5	—	—	—	1 c III D	d IV ε	„	„	♂ III
129.0	c	1	1 b II	1 c III D	— IV —	Oct. 72	„	
130.0	c	2	2 b III	1 c IV D	— IV —	Juni 75	„	
131.0	c	2	1 b II	1 b II C	d III ♂	Dec. 75	Eckernförde	23 + 12 = 35 Kielschuppen
132.5	c	2	2 b II	1 c III D	— V —	Juni 75	Kiel	
133.2	—	—	—	1 c III D	d IV ε	9. April 78	„	♀ VI ?
135.0	c	1	1 b II	1 b III C	— IV —	Juni 75	„	
135.0	c	2	2 b II	1 c III C	— III —	Oct. 72	„	
135.0	c	1	2 b II	1 b III C	d IV ε	März 77	Eckernförde	
136.0	c	2	2 b II	1 b III C	e IV ε	Oct. 76	„	
136.0	c	1	2 b II	1 c III C	e IV ε	Mai 77	„	
136.0	c	1	1 b II	1 c III C	d III ♂	Dec. 75	„	23 + 12 = 35 Kielschuppen
137.0	c	1	1 c II	1 b III C	— III —	Juni 75	Kiel	
137.8	c	2	2 a II	2 c III C	d III ♂	März 77	Eckernförde	23 + 12 = 35 Kielschuppen
138.7	—	—	—	1 b III D	e — —	9. April 78	Kiel	♀ VI-VII
138.7	—	—	—	1 c III C	e III ε	„	„	♂ IV-V
139.0	c	2	2 b II	1 c IV C	e IV ε	März 77	Eckernförde	
139.2	c	2	2 b III	1 c III D	— IV —	März 76	Kiel	
139.3	c	2	3 a I	1 c III E	e III ε	März 77	Eckernförde	
139.4	c	2	1 b II	1 c V D	d IV ε	Oct. 76	„	
141.5	—	—	—	1 b III D	d IV ε	9. April 78	Kiel	♀ VI
142.5	—	—	—	1 c III D	e III ε	„	„	♀ VI-VII
146.5	—	—	—	1 c II C	e III ε	„	„	♀ II
148.0	—	—	—	1 b III D	e IV ε	„	„	? II
149.5	—	—	—	1 b III D	e III ε	„	„	♀ VI

Table XVIII. Sprat from the lower Elbe

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- place 5- date 6- Lower Elbe

Totallänge mm ①	Seitliche Kopflänge ②	Formel ③ der Höben, Längen und Kielschuppen				Datum ④	Ort ⑤
96.3	c	2	1 c III	1 c III E	e III e	Nov. 77	Unter-Elbe
103.0	b	2	1 — III	1 c IV E	e IV e	„	⑥ „
109.0	c	2	o b III	1 c III D	e III e	„	„
115.0	c	2	o d III	o d III E	e IV e	„	„
116.3	—	2	— 1 d IV	2 d IV E	e III e	„	„
119.2	c	2	o c III	1 c III E	e III e	„	„
120.0	c	2	— 1 c IV	1 c IV E	d III ∂	„	„
122.0	c	2	o d IV	2 c IV D	e III e	„	„
122.0	—	2	o c IV	1 b II E	e III ∂	„	„
122.0	c	2	o c III	o c III E	e III e	„	„
122.0	c	2	o c IV	2 c III E	e IV e	„	„
123.0	c	2	— 1 c III	1 c III D	e III e	„	„
124.0	c	2	o c IV	1 c III F	e IV e	„	„
125.0	c	2	o b III	1 d III E	e III e	„	„
125.7	c	2	o c III	1 c IV F	e III e	„	„
127.0	c	2	o c III	1 d III D	e III e	„	„
130.0	c	2	o b IV	1 c III D	e III e	„	„
132.2	c	1	1 b —	2 c III C	e III e	„	„
133.5	c	2	o c III	1 c III E	e IV e	„	„
134.0	c	2	o b III	1 d III E	e IV e	„	„

Sprat are so similar to herring, not only in the shape of their body, but also in their life cycle that a more exact investigation of this fish inevitably seems desirable for the purpose of our research. Unfortunately, what I can offer here is only scanty. In Tables XVII and XVIII, slightly more than 100 sprat with total lengths from 23.5 to 149.5 mm are listed with information on their external body form; however, we have not yet been able to observe sprat regularly in Kiel Bay in all seasons, determine the spawning time, and follow larval development or the growth of fully developed fish. A knowledge of all of these aspects is very important, since there is no better source of insight into the nature of an enigmatic species like the Herring than to compare it in detail with a closely related species. I shall begin by referring to Part One of my investigations and repeating the most essential differences between Clupea sprattus and Clupea harengus. (See Fig. 9 and Fig. 11).

1. Sprat are shorter and taller than herring.
2. The lateral head length is shorter.
3. As a rule, the anal fin is longer and has more rays than the dorsal.
4. The keel scale numbers are generally smaller.
5. The number of rays in the ventral fin is smaller (= 7).
6. The number of vertebrae is smaller.
7. The locations of the fins and anus are different. Characteristic formula: 1cIIIC.
8. The shape of the head, and the dentition of the gill arches and the vomer, are different.

In behavior, sprat seem to differ from herring in that, at least in the Baltic, they are purely ocean fish, and avoid brackish water. From the North Sea, they enter the mouth of the Elbe, as the herring do.

1. I have investigated only two local forms of sprat--from Kiel Bay (Figure 11) and from the Lower Elbe (Figure 12). A comparison of these two forms will suffice to persuade the reader that there are different races of sprat as well as of herring. Similar conditions of life seem to affect the body shape in the same way in both species; Elbe

sprat, like Elbe herring, are differentiated from all other members of their species by their great body height. Incidentally, this peculiar type of sprat was described already in 1853 by KROYER in the third volume of his work Danmarks Fiske ['Fishes of Denmark'], under the name Clupea Schoneveldii. He found them in the Sund, Isefjord and some fjords in Jutland.

2. Another result of my investigations which is shown by Table XVII is much more important than the demonstration of local forms of Clupea sprattus: In Kiel Bay, there are two races of sprat living together: an autumn form and a spring form. I owe the discovery of this fact to the circumstance that two different types of sprat brood were found. The first occurs in large numbers in the inner parts of Kiel harbor in July and August, and comprises individuals which are in the transitional stage, with total lengths from 25 to 35 mm. Fourteen of the individuals listed in the first part of Table XVII belong to this group. They were undoubtedly spawned in spring by parents of a race which spawns in April or May in the salt water of the open bay. The sexually mature spring sprat can be easily observed; in Table XVII, there are four sprat with total lengths of 138 to 150 mm caught while spawning in Kiel Harbor on April 9, 1878. The other sprat brood is found in the salt water of Kiel Harbor from the end of October to December. Sixteen of these fish, with total lengths from 23.5 to 33.5 mm, are listed in Table

XVII. All, without exception, are larvae, and were caught in November and December together with autumn herring larvae of the same size. They can be readily differentiated from the herring larvae by their orange hue, taller and more thickset shape, more developed ventral fins, and finally, by the fact that the swim bladder, which can be seen through the skin, is already oblong in the sprat larvae, while it is still small and globose in herring larvae of the same size. With a microscope, sprat larvae can be easily recognized by the lower number of vertebrae.

If we compare the two broods of Clupea sprattus more closely, we find the very same differences which exist between the offspring of Var. A and B herring. This can be seen immediately by considering the following three pairs of individuals, which are coupled by braces in Table XVII:

25.0-c-5- 0bII-	spring, transitional stage
25.5-e-7- -2d0A-	autumn, larva
27.0-b-6- 1cIII-	spring, transitional stage
27.0-d-7- -2cIB-	autumn, larva
29.0-c-5- 0cII-	spring, transitional stage
29.0-d-6..-2cI	autumn, larva

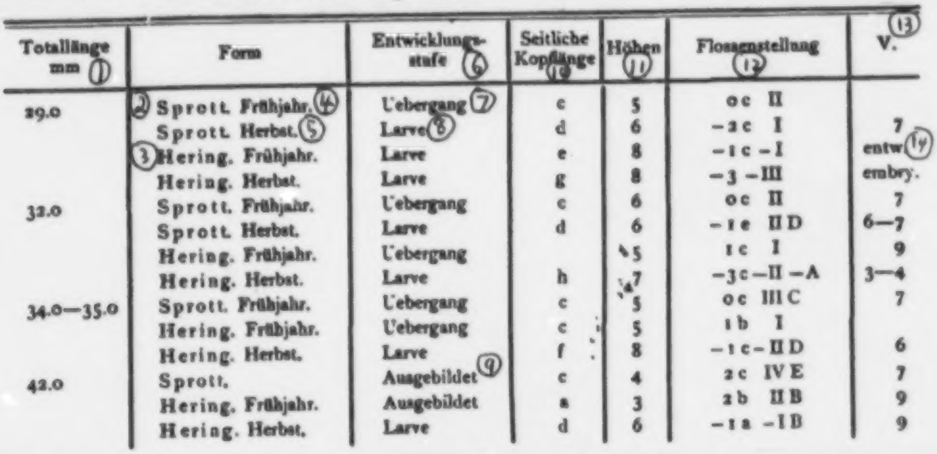
Observe that the autumn form lags behind the spring form in every respect with the exception of the ventral fin location; its lateral head length and body height are smaller; the dorsal fin and the anus are located much farther back; and finally, the ventral fins are much less developed. When the autumn form is still in the larval stage, the spring form has already entered the transitional stage. The spring sprat will probably attain their definitive form already at a length of 33 to 35 mm, while the autumn sprat will probably mature with 43 to 45 mm, at the earliest.

It would be interesting to pursue the discussion of the parallelism which we have just discovered between sprat races and herring races, but we must not succumb to this temptation yet. For, unfortunately, so far no research has been undertaken on adults of these two races (autumn and spring sprat) which are ripe for spawning, although both undoubtedly exist; when and where they spawn remains obscure. The exact determination of all of these data will be one of the first tasks for whoever wishes to study more exactly the causes of the development of races in Kiel Bay. Since similar effects imply similar causes, and the differences of form between autumn and spring broods are exactly the same in the case of Clupea sprattus as in that of Clupea harengus, we may conclude that the respective conditions in which spring and autumn fish of both species are hatched and begin their larval development each include some common features which must be regarded as the causes of those differences.

3. It is also interesting to compare the morphological development of the individual in herring and sprat. The latter attain their definitive form much sooner than the

herring, probably at a length of 35 to at most 45 mm (whereas herring are fully developed only at 42- 60 mm total length). Similarly, young sprat anticipate herring in the growth of fins and fin rays, and swim bladder.

The following survey of individuals of both species may serve to illustrate this pattern:



Totallänge mm ①	Form	Entwicklungsstufe ⑥	Seitliche Kopflänge ⑩	Höhen ⑪	Flossenstellung ⑫	V. ⑬
29.0	② Sprott. Frühjahr. ④	Uebergang ⑦	c	5	oc II	
	Sprott. Herbst. ⑤	Larve ⑧	d	6	−2c I	7
	③ Hering. Frühjahr.	Larve	e	8	−1c −I	entw. ⑭
	Hering. Herbst.	Larve	g	8	−3 −III	embry.
32.0	Sprott. Frühjahr.	Uebergang	c	6	oc II	7
	Sprott. Herbst.	Larve	d	6	−1e IID	6—7
	Hering. Frühjahr.	Uebergang		5	1c I	9
	Hering. Herbst.	Larve	h	7	−3c −II −A	3—4
34.0—35.0	Sprott. Frühjahr.	Uebergang	c	5	oc IIIC	7
	Hering. Frühjahr.	Uebergang	c	5	1b I	
	Hering. Herbst.	Larve	f	8	−1c −IID	6
42.0	Sprott.	Ausgebildet ⑨	c	4	2c IVE	7
	Hering. Frühjahr.	Ausgebildet	a	3	2b IIB	9
	Hering. Herbst.	Larve	d	6	−1a −IB	9

Key: 1- total length 2- sprat 3- herring 4- spring 5- autumn 6- developmental stage 7- transitional 8- larva 9- fully developed 10- lateral head length 11- height measurements 12- fin locations 13 and 14- See p. 188 of the translation.

Examining this table more closely, we find that:

a. The sprat usually anticipate the herring in their level of development. Autumn sprat of 31 to 34 mm total length which are still larvae are an exception when compared with same-sized spring herring which are already in the transitional stage.

b. The type of differentiation observed in the two species is very different. In particular, the relative locations of the ventral fins and the anus are always different in sprat than in herring.

c. In some characters, young sprat resemble adult herring (viz., the location of the anus and the length of the base of the anal fin); in others, young herring resemble adult sprat (viz., the dorsal and ventral fin locations and the number of rays in the ventral). At no time during development does a younger stage of one species resemble adults of the other species in every respect.

If we assume that sprat descended from herring, or herring from sprat, this does not support HÄCKEL's 'biogenetic law', according to which the later species should recapitulate the ancestral form in its development.

Chapter Four

Herring and Sprat

A Darwinian view

The purpose of my exposition in this chapter is to verify the accuracy of the theory of transmutation in the case of the material furnished by my investigations on herring.

It might seem as if discussion of the theory of descendence would be superfluous in the present treatise and completely unrelated to the actual goal of our research, i.e., explaining the development of herring races and its causes. This is quite erroneous. On the contrary, I hope to convince the reader that in the present case, both questions are inseparable, and that any attempt to explain the development of races from the effects of different environmental conditions is equivalent to an investigation concerning the origin of species. Readers who, in result of their own observations or studying the works of Darwin, are convinced of the truth of the transmutation theory will accept this even without further proof.

1. The variability of Herring (Clupea harengus)

I have already explained at length in Part One (p. 60 ff.) that the conventional type of systematic description is completely unsatisfactory even quite apart from the theory of descendence. GÜNTHER's diagnoses of herring and sprat fit at best 10 % of the individuals which I investigated. Here I can only confirm what was stated previously, and I should add that, now that I have studied ten or twelve characters in each individual instead of five, neither GÜNTHER's diagnoses nor those of any other author fit even one of the individuals which I have examined. The reason for the uselessness of systematic descriptions is essentially that too few conspecific individuals are compared, the characters are selected in a biased or completely random fashion, and peculiarities of form arising from sex and growth are practically disregarded. My own improved method is already familiar to the reader. The necessity of a detailed description of many individuals produced it, and I believe that the results have established its usefulness.

When we review all of the tables attentively, the extraordinary variability of all the characters in herring is surprising. The following table shows the variability of the most important characters, disregarding, of course, all individuals in the larval or the transitional stage:

Character	*Number of individuals examined*	*range of variation*	*formula*
1. number of vertebrae	127	58-51	
2. total number of keel scales	500	48-37	0 to δ
3. keel scales between head and ventrals	500	32-25	0 to c
4. keel scales between ventrals and anus	860	20-11	-I to IV
5. number of rays in ventral fin	?	10-7	-
6. number of rays in anal fin	?	15-20	-
7. length of base of anal fin	908	76-118	0 to c
8. dorsal fin location	1005	2.45-2.08	4 to 1
9. ventral fin location	1005	1.95-2.24	0 to d
10. location of anus	935	1.44-1.63	0 to IV

These data require hardly any commentary. The extraordinarily wide range of variation of all the characters is striking, especially in the case of the first six, which involve simple counts of the same item. To reveal clearly the variation of the body measurements, it may be noted that in a herring of 230 mm total length, the range of variation in the location of the dorsal fin involves a difference of almost 18 mm, with corresponding values of 15 mm for the ventral fin and 10 mm for the anus. Variation of the length of the base of the anal fin is enormous. For an individual measuring 230 mm in length, this measurement is normally 23 mm, or 10 % of total length. The range of variation corresponds to a difference of 10 mm in length, or nearly half of the average size.

Our systematic handbooks, because of their inadequate method, do not reflect in their descriptions the actual variation observed in any single species. Who would imagine, on reading a systematic catalogue, that all of the species which are so precisely delineated on paper, defy these descriptions in reality? Such descriptions are like magic circles of carefully arranged words and symbols, in which no living thing is enclosed.

Still, the existence of such great intraspecific variation in itself would not have any scientific value, if it did not simultaneously manifest a law which is as important as it is simple: The variability of a species increases with the number of individuals examined.

The following concise tabulation of the number of keel scales between ventrals and anus may serve to exemplify this almost universal law:

The range of variation after examining...

126	individuals	was	12 to 16
400	"		12 to 17
520	"		12 to 18
620	"		11 to 19

700 " 11 to 20.

This law applies to combinations of characters even more than to individual features. With every hundred additional herring examined, combinations appear which could not be imagined after an initial investigation of a few specimens. When I wrote Part One of these investigations, I would have thought it impossible that herring would occur with such formulae as IcIIIB, 2cIVC, or 1aIIIC; now, it seems to happen every day.

But while formal variation within the species Clupea harengus may be great, and will certainly become greater as more specimens are examined[1], it is not irregular and chaotic. That has been demonstrated by the entire preceding part of this study, which showed that most variations can be combined into three major groups, A, B, and C, which should be regarded as resulting from certain external conditions. However, outside of these groupings-- or better, scattered within them-- are a number of combinations which are at the limits of the species and show definite links with other closely related species, particularly Clupea sprattus. A study of these borderline cases, and an exact comparison of herring and sprat will not only be interesting in itself, but may also help to establish the nature of the three major herring races more concretely.

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[1] The variation will not be unlimited. The probable result of continuing investigations examining billions of individuals would be that new forms would appear less and less frequently.

2. Comparison of herring and sprat

a. In order to fulfill this task in the most concise and meticulous way possible, I shall follow the same procedure used in Part One (p. 55 ff.). I shall determine the range of variation for each species, and their common range of variation. The respective characters will be ranked for their diagnostic value on the basis of the relative size of the common range, or the size of that common range in proportion to the entire range covered by both species together. As this ratio becomes smaller, the difference between the two species in the character in question becomes greater.

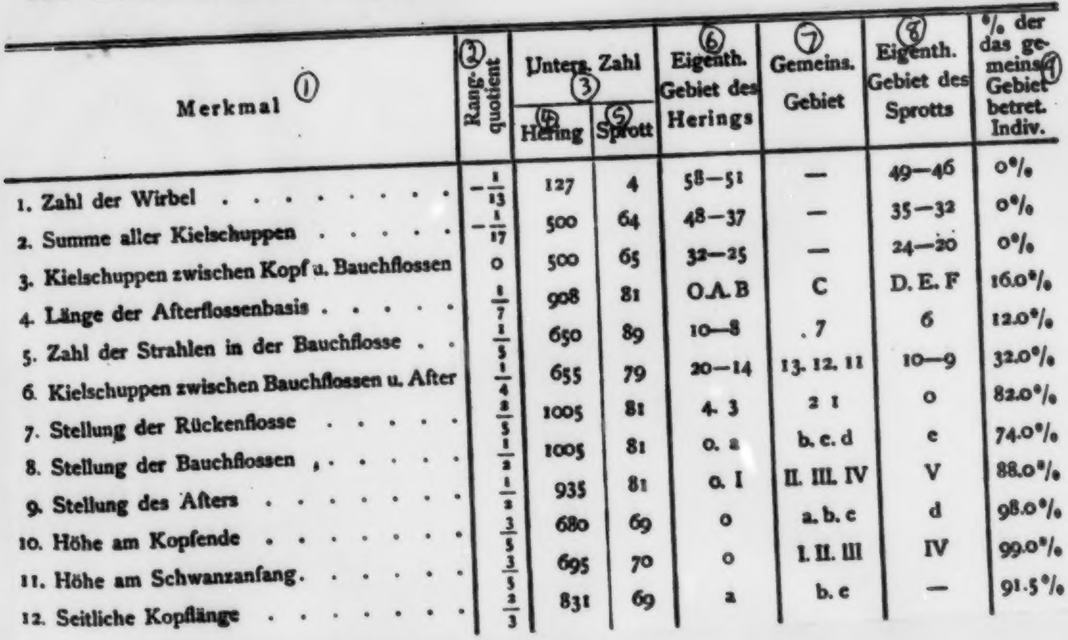
When there is no common range of variation, there are two possibilities. Either the respective ranges of the two species are directly adjacent (as in the case of character 3 in the comparison table), or else there is a gap between them which is not entered by either species (characters 1 and 2 in the table). In the first case, the ranking of the character in question is expressed by the ratio $0/x = 0$, with x= the distance between the extremes of both variation series. In the second case, however, the ranking ratio is $-a/x$, or a negative number (a= the size of the gap).

Comparison of sprat and herring

Key: 1- character 2- rank 3- number of individuals examined 4- herring 5- sprat 6- intraspecific range of herring 7- common range 8- intraspecific range of sprat 9- percentage of individuals falling in the common range

Numbered characters:

1. number of vertebrae
2. total number of keel scales
3. keel scales between head and ventrals
4. length of the base of the anal fin
5. number of rays in the ventral fin
6. keel scales between ventrals and anus
7. dorsal fin location
8. ventral fin location
9. location of anus
10. height at the back of the head
11. height at the beginning of the tail
12. lateral head length



Merkmal ①	② Rang-quotient	③ Unters. Zahl		⑥ Eigenth. Gebiet des Herings	⑦ Gemeins. Gebiet	⑧ Eigenth. Gebiet des Sprotts	⑨ °/₀ der das gemeins. Gebiet betret. Indiv.
		④ Hering	⑤ Sprott				
1. Zahl der Wirbel	$-\frac{1}{13}$	127	4	58—51	—	49—46	0°/₀
2. Summe aller Kielschuppen	$-\frac{1}{17}$	500	64	48—37	—	35—32	0°/₀
3. Kielschuppen zwischen Kopf u. Bauchflossen	0	500	65	32—25	—	24—20	0°/₀
4. Länge der Afterflossenbasis	$\frac{1}{7}$	908	81	O.A.B	C	D. E. F	16.0°/₀
5. Zahl der Strahlen in der Bauchflosse . .	$\frac{1}{5}$	650	89	10—8	. 7	6	12.0°/₀
6. Kielschuppen zwischen Bauchflossen u. After	$\frac{1}{4}$	655	79	20—14	13. 12. 11	10—9	32.0°/₀
7. Stellung der Rückenflosse	$\frac{2}{5}$	1005	81	4. 3	2 1	0	82.0°/₀
8. Stellung der Bauchflossen , ...	$\frac{1}{2}$	1005	81	o. a	b. c. d	e	74.0°/₀
9. Stellung des Afters	$\frac{1}{2}$	935	81	o. I	II. III. IV	V	88.0°/₀
10. Höhe am Kopfende	$\frac{3}{5}$	680	69	o	a. b. c	d	98.0°/₀
11. Höhe am Schwanzanfang.	$\frac{3}{5}$	695	70	o	I. II. III	IV	99.0°/₀
12. Seitliche Kopflänge	$\frac{2}{3}$	831	69	a	b. c	—	91.5°/₀

Among the twelve characters listed, there are only three in which all herring differ from all sprat, so that these are reliable diagnostic features. However, it should be noted that precisely in the case of these three characters, the number of individuals examined was lower than in other cases. Hence it is quite possible, even highly probable, that continued research will reveal a common range for herring and sprat also in the number of vertebrae and keel scales. It is especially likely in the case of the number of keel scales between head and ventrals, since in this case the exclusive ranges of the two species are already directly adjacent. Among the other nine characters, four have common ranges with a relative size smaller than ½, and five have common ranges with a relative size equal to or greater than ½. The number of individuals falling within the common range is generally proportional to the relative size of that range.

Let us now inquire how herring and sprat are related if we consider the four major combinations of characters instead of isolated characters. Naturally, we shall exclude all characters without any common range of variation. Table XIX in the Appendix presents a convenient list of 22 herring and 18 sprat which, among all the fish which I examined, showed the closest approximation of both species to each other. Now the question arises, whether there are herring or sprat which are intermediate in the combination of the eight characters having a common range (with the exception of the number of rays in the ventral fin) --i. e., are there cases in which all eight characters fall within the common range? In Table XIX (see Appendix) there are ten sprat and one herring (marked with asterisks) which satisfy this condition, and which therefore-- as long as we deliberately consider only these eight characters-- can neither be designated as herring nor as sprat. If, instead of eight characters, we consider only seven or even fewer, obviously the number of intermediate individuals increases as the number of combined characters decreases. It may be recalled that in Part One, I could still state that even in the combination of four basic characters, herring and sprat were already completely different from each other; now that we have examined a much larger number of individuals, this can no longer be maintained.-- I shall designate all individuals which are intermediate in only some of the characters as 'incompletely intermediate'; those which fall within the common range in all characters are 'complete intermediates'.

One very peculiar individual, the most remarkable specimen which I examined, is the fish with a total length of 79 mm marked with two asterisks in Table XIX. I have already introduced this strange creature in Part One (p. 125). If we consider only the nine characters b-bI-3cIVB-III, ventr. 8, it must be classed as a herring, since 3, B and 8 fall within the exclusive range of Clupea harengus, while the other characters are in the common range. If we add the keel scale numbers (24 + 12= 36), 24 is in the exclusive range of sprat, while 36 falls mid-way between the exclusive ranges of both species. Thus, this individual falls within the exclusive range of herring in three characters (3, c, and 8), within the sprat range in one (24), in the common range in seven, and half-way between herring and sprat in one (36). I should like to coin the term 'mixed' for individuals such as this, i.e., those with all, or, as in this case, some characters falling into the exclusive ranges of both species simultaneously. The former may be designated as 'completely mixed', the latter as 'incompletely mixed'. As a rule, incompletely mixed individuals approximate more closely to either herring or sprat, and can easily be associated with the species which they most resemble by changing the table. In the present case, we need only move 36 into the exclusive herring range for the number of keel scales, and shift 24 from the side of sprat into the common range for the number of keel scales between head and ventrals. Then the 'mixed' form will become a herring very closely resembling sprat, or if we prefer, an incomplete intermediate in the eight characters b-bII-cIV-dIIIδ. Thus, our peculiar individual can still be designated specifically as a herring, but at the same time forms a new link between the two species by producing a common range of variation in one of the most important differentiating characters, namely the number of keel scales between head and ventrals. Now the only remaining characters among those which we have investigated which still separate the species reliably are the number of vertebrae and the total number of keel scales.

Completely and incompletely mixed forms such as this, which are equally close to sprat and to herring, have not yet been found in my research. They would have to have combinations like the following:

a - dIV - 3eID - 23 + 18.41. Vert. 55. Ventr. 7. (completely mixed)

b - bII - 2cIIIC - 26 + 10.36. Vert. 49. Ventr. 9. (incompletely mixed).

I do not believe that individuals with such combinations ever occur, unless they occasionally result from crossing of the two species. Perhaps they can not be produced in nature, because they violate some irreversible mechanical laws of body structure or the like.

Complete intermediates in all twelve characters listed in the comparison table would include:

1. b - bII -2cIVC - 24 + 12.36. Ventr. 7. Vert. 50.
2. c - bII - 1cIIIC - 24 + 12.36. Ventr. 7. Vert. 50.

The closest approximation of the first of these two combinations is the herring of 79.0 mm total length discussed previously; the closest approximation of combination two is the sprat in Table XIX with a total length of 131.0 mm.

In the number of vertebrae, most sprat come very close to the required number; the number 49 is not infrequent among sprat, and it is very likely that 50 will occur before more than 100 sprat are investigated. Herring are farther away from the number 50; the two herring which came closest to this number had the following formulae:

1. 215.5 - bI - 2bIIIC - cIIIγ. 16 May 78. Schlei. ♂
VII. 53. V. 9

2. 201.0 - bII - 3bIIIB - cIIIγ. 16 May 78. Schlei. ♂
VII. 51. V. 8.

Notice that both of these individuals show a strong tendency towards sprat also in the other characters.

Figures 13 and 14 illustrate the great similarity which can exist between herring and sprat in their external body form. Figure 14 is drawn from a young herring of 155 mm total length, Figure 15 from a sprat of 135 mm total length. The results of our comparison of herring and sprat may be summarized as follows:

1. *Clupea harengus* and *Clupea sprattus* are two distinctly different groups of individuals-- I call them species-- because: a. they have qualities with no common range of variation; b. there are no completely mixed forms; c. there are no incompletely mixed forms which resemble both groups equally; and d. there are no complete intermediates.

2. Clupea harengus and Clupea sprattus are very similar, closely related species because: a. several characters have a common range of variation with a relative size frequently exceeding ½; b. incompletely mixed types occur, albeit infrequently, which are inclined towards one species or the other; c. 'incomplete intermediates' occur in the combination of all characters having a common range of variation (ca. 2 % of the total material).

Using the comparison table, it is possible to represent the degree of difference vs. similarity between the two species by means of a simple numerical expression. This is shown by the following consideration.

Let us assume that both groups under comparison have only common ranges of variation in all characters investigated, i.e., neither group has any exclusive characters. Obviously, then the ranking of every character would equal x/ x or 1/ 1.

I describe two such groups of individuals as completely similar, although it is conceivable, and in fact happens, that in spite of the absence of exclusive ranges of variation, they exhibit some degree of difference. Thus, for example, the anal fin is sometimes shorter, and sometimes longer than the dorsal in both herring and sprat, so that there is no exclusive range of variation. Nevertheless, the two species are somewhat different even in this character, insofar as cases in which the anal fin is longer than the dorsal are more frequent among sprat, while those in which it is shorter are more frequent among herring. The rule for one species is the exception for the other.

Groups of individuals which do not even exhibit differences like those which I have just described-- i.e., groups in which all respective levels of the common range of variation occur in equal percentages-- I designate as 'identical'[1].

Now let us take a third case, which is the exact opposite of 'complete similarity'. Let us assume that certain organs or particular features of organs occur only in one group, and never in the other. For example, there are species of the family Clupeidae in which ventral fins are completely absent; herring have these fins, and they have ten rays. Now let us assume that the number of rays in the ventral fin is absolutely constant in herring, with the value 9; then the ranking of this character would he calculated as follows: The species without ventral fins has 0 rays, herring has 9. Therefore the extreme values of both ranges are 0 and 9, and the interval between them = 9. The gap between the species is equally large, and therefore, according to the procedure indicated previously (p. 51), = (-9). This yields a ranking ratio = -9/ 9 = -1/ 1. I describe groups in which this pattern occurs in all characters as 'completely different'. Every feature observed in these organisms is completely absent in one group and absolutely constant in the other. The reader may suppose that 'completely different groups of individuals' in the sense just defined never occur in nature. For, we never encounter a group of any size which is composed of individuals in which all features are completely constant. However, many groups come very close to being 'completely different'-- e.g., the seven divisions of the Animal Kingdom, etc. In these groups, as a rule, a good number of features are absolutely constant, such as the presence of the spinal cord and the brain in vertebrates.

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[1] [Translator's note:] The German word gleich can mean either 'similar' or 'identical'. The author used this word above for species with no common range but some degree of difference, which he will later treat as the opposite extreme to species which he calls 'completely different'. The English language, with its sharp distinction between 'similar' and 'identical', does not tolerate this ambiguity. In order to minimize the inevitable awkwardness of these pages in English, I have translated gleich as 'completely similar' and absolut gleich as 'identical'.

Between complete similarity and complete difference, there are an indefinite number of degrees of partial difference. The comparisons of systematists are concerned almost exclusively with these degrees. Since the conventional method of differentiating groups of individuals must be entirely rejected, any attempt-- including that which follows-- to initiate a rational procedure should be welcome. Let us assume that, as in the present case with herring and sprat, twelve characters of each group have been studied. If we add together the ranking ratios of all the characters, we shall have the value 1/ 1 x 12 = 12 for complete similarity, and -1/ 1 x 12 = -12 for complete difference. For partial differences, the number will be between +12 and -12. In the case of herring and sprat, the sum of all the ranking ratios is +3.5. Thus the range from complete similarity to complete difference obviously comprises 24 levels of equal size. Herring and sprat have covered 12 - 3.5 = 8.5 of these levels, or 0.35 of the entire range. I shall designate the number 0.35 provisionally as the degree of difference of sprat and herring. It can generally be calculated from the formula

$$\frac{m - (rq_1 + rq_2 + \ldots rq_m)}{2\ m}$$

where m is the number of characters investigated, and rq_1, rq_2, etc. are their respective ranking ratios. If the sum of all ranking ratios is = +m, then the degree of difference = 0/ 2m = 0 (level of complete similarity); if the sum of all ranking ratios = -m, then the degree of difference = 2m/ 2m = 1 (level of complete difference). Finally, if the sum of all the ratios = 0, this gives a degree of difference m/ 2m = 1/ 2, i.e., the two groups are exactly halfway between complete similarity and complete difference. This will happen either if the ratio for all the characters is 0, or if it is positive for some characters and negative for others, so that the sum is still 0. The first case may never occur, or at best will be extremely rare.

The scientific value of the figure which I have designated as the 'degree of difference' depends entirely on the type of comparison. First, it is clear that in every case it is a relative value, since we can never investigate all of the characters. The question, then, is how we can obtain a value which approximates as closely as possible the actual degree of difference. Since experience shows that two groups of individuals may be very different in some characters and very similar in others, evidently the best way to reach this goal will be to select those characters in which the greatest difference occurs, and those in which there is the greatest similarity, and investigate the largest possible equal number of characters from both character groups. In other words, for an accurate assessment of the relation between two groups of individuals, we should assess their similarity and their differences in equal measure. Systematics has frequently erred by neglecting this principle; usually all efforts have been directed towards discovering differences, and the similarity, which was often far greater, has been overlooked.

The question arises whether, in the present case, our value of 0.35 for the degree of difference between herring and sprat is too high or too low. Probably it is too low. For, when I made the comparison, my attention was directed chiefly to discovering differences. I have already noted that neither species has an exclusive range in the relative length of the anal and dorsal fins; this may also be true for very many other characters, and their ranking ratio would reduce the degree of difference. On the other hand, however, we must also remember that there are probably characters which have not yet been considered, in which sprat and herring differ even more than in the number of vertebrae-- e.g., perhaps the vomerine teeth, or the formation of the gill strainer. These would then again widen the degree of difference.

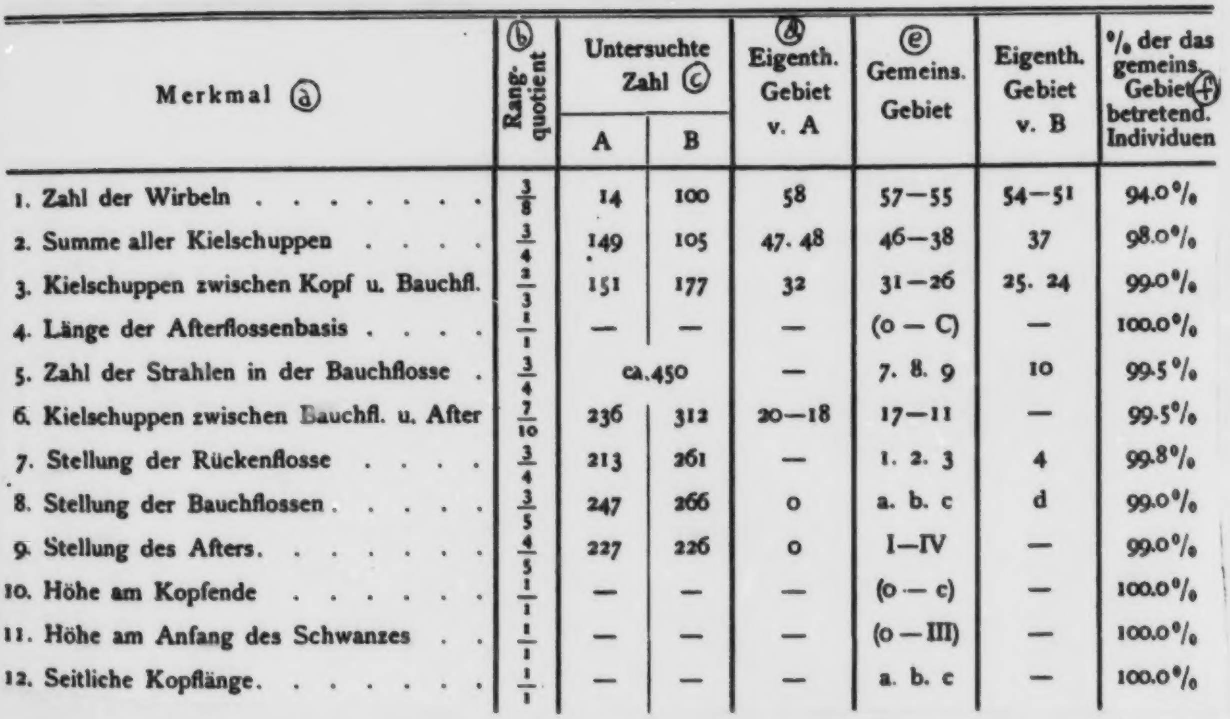
In this case, in my opinion, the most rational way of approximating the actual degree of difference as closely as possible would be to analyze the entire external habit of herring and sprat by taking numerous linear measurements and counting equivalent parts (such as scales, etc.), while leaving the internal organs out of consideration. For if there are truly important differences inside as well, according to the law of correlation, they would have to be expressed in the external habit. On the other hand, one could also disregard the external habit and study only internal organs, such as the entire skeleton. It would be much more irrational to study internal and external organs together: There would be a greater risk of neglecting major similarities, because each individual organ would have to be studied part by part, and our mentality is more inclined to discover differences than correspondences. Finally, also the size of the respective variation levels represented by letters or numbers will affect degrees of difference. By defining smaller variation levels, we can determine more accurately the ratio of the common range of variation to the total range for both species, or the ranking ratio. Therefore, whenever possible, the variation levels used should be no greater than is necessary to compensate unavoidable errors of observation.

3. The herring races in relation to both species

The reader is probably satisfied that the racial differences which I demonstrated are related to direct effects of environmental conditions. It is also clear that the formal differences between herring races are small, so that varieties A and B, for example, are obviously not far apart in their degree of similarity compared to two species, like herring and sprat. Hence, if, with Darwin, we regard varieties as incipient species, the herring races are particularly interesting, not only because they show an early stage of speciation, but also because at the same time the external impetus-- the influence of different living conditions-- is clearly manifested. The best way to approach this matter will be to compile for varieties A and B the same kind of comparison table which we compiled for herring and sprat. I included in group A (p. 45) the spring herring from Peterhead, Bohuslan, Korsör, and Kiel, spring herring spawning in salt water from Bergen, Langeland, and Kiel, and finally the Elbe herring. In group B, I classed the spring herring spawning in brackish water from Kiel and Dassow.

Comparison of Var. A and Var. B

Key: a- character b- ranking c- number of individuals examined d- exclusive range e- common range f- percentage of individuals falling within the common range
1- number of vertebrae
2- total number of keel scales
3- keel scales between head and ventrals
4- length of the base of the anal fin
5- number of rays in the ventral fin
6- keel scales between ventr. and anus
7- dorsal fin location
8- ventral fin location
9- location of anus
10- height at the back of the head
11- height at the beginning of the tail
12- lateral head length



Merkmal ⓐ	ⓑ Rang-quotient	Untersuchte Zahl ⓒ		ⓓ Eigenth. Gebiet v. A	ⓔ Gemeins. Gebiet	Eigenth. Gebiet v. B	% der das gemeins. Gebiet ⓕ betretend. Individuen
		A	B				
1. Zahl der Wirbeln	$\frac{3}{8}$	14	100	58	57—55	54—51	94.0%
2. Summe aller Kielschuppen	$\frac{3}{4}$	149	105	47. 48	46—38	37	98.0%
3. Kielschuppen zwischen Kopf u. Bauchfl.	$\frac{2}{3}$	151	177	32	31—26	25. 24	99.0%
4. Länge der Afterflossenbasis	$\frac{1}{1}$	—	—	—	(o — C)	—	100.0%
5. Zahl der Strahlen in der Bauchflosse .	$\frac{3}{4}$	ca. 450		—	7. 8. 9	10	99.5%
6. Kielschuppen zwischen Bauchfl. u. After	$\frac{7}{10}$	236	312	20—18	17—11	—	99.5%
7. Stellung der Rückenflosse	$\frac{3}{4}$	213	261	—	1. 2. 3	4	99.8%
8. Stellung der Bauchflossen	$\frac{3}{5}$	247	266	o	a. b. c	d	99.0%
9. Stellung des Afters.	$\frac{4}{5}$	227	226	o	I—IV	—	99.0%
10. Höhe am Kopfende	$\frac{1}{1}$	—	—	—	(o — c)	—	100.0%
11. Höhe am Anfang des Schwanzes . .	$\frac{1}{1}$	—	—	—	(o — III)	—	100.0%
12. Seitliche Kopflänge.	$\frac{1}{1}$	—	—	—	a. b. c	—	100.0%

The table shows that varieties A and B each have exclusive ranges in some characters: A has them in the number of vertebrae, the numbers of keel scales, the location of the ventral fin, and the location of the anus; while B has them in the number of vertebrae, the number of keel scales between head and ventrals, the total number of keel scales, the number of rays in the ventral fin, and the dorsal and ventral fin locations.

For all characters, the common range for both varieties is wider than it is in the same character for both species. However, in the case of the ventral fin location, it is only slightly wider (1/10 wider; 3/5 vs. 1/2).

Whereas the species have three characters (or, as we shall see later, at least one) without a common range, this does not happen in the case of the two races; on the other hand, the races have four characters with a common range = 1/1-- i.e., without any exclusive ranges.

Moreover, the ranking is different for the two varieties than for the species. For, only half of the characters-- viz., the number of vertebrae, the number of keel scales between head and ventrals, the dorsal fin location, the two height measurements, and the head length-- have the same rank; the others do not.

If we add the ranking ratios, their sum is 8.6. According to the formula given above (p. 54), this yields a degree of difference = 0.14. This result can be translated into words as follows: Between the herring varieties A and B, on the one hand, and the two species herring and sprat, on the other hand, there is only a difference of degree. On a scale from complete similarity to complete difference, the two races have progressed only as far as 0.14 of the way; the two species have already progressed 0.35 of the way; therefore they are ahead of the varieties by a margin of 0.21. At the same time, the species already have characters without a common range, while the races do not.

The earlier chapters of this treatise have shown that the difference between the races is connected with the influence of different environmental conditions. From Darwin's point of view, then, it can safely be assumed that at one time, both races were completely similar, and that one originated from the other, or else both had a common origin. But then it is also conceivable, indeed probable, that continued and increasing action of the same environmental conditions which produced the presently existing difference will cause even greater difference in the course of time. The autumn herring of the Kattegat, in which type A is expressed more distinctly than in the autumn herring of Kiel Bay, indicate the possibility of such a process. Now if the sum of all ranking ratios for both varieties were reduced by (8.6 - 3.5)-- or, what amounts to the same, if the ranking ratios of the individual characters were each reduced by an average of 5.1/ 12 = 0.42-- then the two varieties would be as different as herring and sprat. And if, at the same time, the common range of variation were to disappear completely in one or more characters, then these two races would represent groups of the very same kind as herring and sprat. In other words: Varieties would have developed into species. If we accept the possibility of the process which I have just described, then we may also assume that herring and sprat were once completely similar and that they acquired their existing differences through the action of different environmental conditions.

A reduction of the common range of variation can come about in either of two ways: by direct reduction of the common range itself, or by expansion of the exclusive ranges of the two forms. I shall designate the former process as the 'extinction of intermediates', and the latter as 'increasing character divergence'. I believe that both processes happen together in nature. I could compile comparison tables for A and C or C and B, just as I have done for A and B, and they would probably look very similar.

I have now reached the conclusion of my Darwinian study, and I shall leave it for the reader to judge whether I promised more than I have achieved, and to what extent my exposition lends support to the theory of transmutation. My aim has been to strike a new, untrodden path for testing this hotly contested theory, and to advance as far along this path as my time and talent would allow. The most important realization resulting from my essay is that the present mode of systematic description must be completely reformed if it is to be made suitable for studying the transformation of organisms. The older method will never suffice to recognize the small, imperceptible changes which result in living organisms from the influence of different environmental conditions. This explains why so many Darwinians believe that agelong changes in the conditions of life in a given region affect only some of the inhabitants of that region, with others left unchanged, while strictly scientific thinking should tell us that all of the species in the region would have to change their particular nature. In my experience, there are no exceptions; but we must know how to recognize the changes. For several years, I have been investigating more than twenty fish species besides herring and sprat in the Baltic and adjacent freshwater sources, and all of them show patterns similar to that descibed here.[1]

Another result of my investigation should also be stressed. Whoever desires to study the transformation of organisms should direct his attention primarily to the developmental stage, to the young animal or plant. What has long been recognized for man-- namely that next to heredity, the rearing of the young individual provides the most important lever for the evolution of our species-- applies to all living creatures. The fully developed, reproductively mature individual, in the majority of cases, is capable of changing only slightly; most transformations which it undergoes relate to the care of the growing brood. But the young themselves are completely malleable, and can respond to the slightest alteration of their environment with an alteration of their inherited form. When the full import of this undeniable truth is recognized by the Darwinians even more than it has been so far, many secrets of species transmutation will be unveiled. And our prevailing conceptions of the relation between ontogeny and phylogeny, which have culminated in HÄCKEL's completely untenable biogenetic law, will be clarified. What a wide and bitter, but futile debate has raged about this law, which is possible only on the presupposition that all changes in organisms occur at the age of reproduction!

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[1] Cf. the study on the fishes of Kiel Bay by MÖBIUS and the present author.

Chapter Five

Hypothesis concerning the origin of herring races

The findings from all of the preceding chapters of this study, taken together, have led me to formulate a certain hypothesis concerning the origin of the brackish-water variety B. At the end of the first section of Chapter One (p. 15), all of the herring found in Kiel Bay were grouped under nine different headings. I differentiated two extremes and one intermediate type in form and in behavior, so that the combination of form and behavior resulted in nine different groups. Here I shall reproduce the distribution given earlier of 280 adult herring among these groups.

autumn herring A	...35 (13.0 %)
spring herring A	...50 (18.4 %)
intermediate A	...29 (11.0 %)
Var. A	..114 (42.4 %)
autumn herring B	... 8 (3.0 %)
spring herring B	...98 (36.) %)
intermediate B	...20 (7.0 %)
Var. B	..126 (46.6 %)
intermediate autumn herring	...2 (0.7 %)
intermediate spring herring	..21 (8.0 %)
intermediate x intermediate	...7 (2.5 %)
Intermediates	..30 (11.2 %)
total autumn herring	16.7 %
total spring herring	62.4 %
total intermediates	20.9 %
	100.0 %

The results of this compilation are quite remarkable:

1. One-fifth (21 %) of all herring have a type of spawning behavior intermediate between true spring and autumn spawners.

2. There are a considerable number of herring (26.4 %) which spawn in spring and have form A or an intermediate form between A and B.

For adherents of the theory of transmutation, there can be only one natural explanation of these findings. Var. A must be the older, primitive type of herring, from which form B evolved-- and is still evolving-- by adaptation to spring spawning in brackish water. The only assumption needed to demonstrate this hypothesis is that in the transmutation of a species, environmental changes are the primary factor, and the associated changes of form are secondary. This assumption is not risky; it has been confirmed by many cases that animals which are introduced into a changed environment remain unchanged for a long time, until the gradual effect of the new conditions finds expression in bodily changes. The reverse situation-- that the body should change first, and then a corresponding change should follow in the conditions under which it lives-- is far less probable, frequently even impossible. We must therefore maintain that at a certain point in time, some individuals of the ancestral form A in Kiel Bay (perhaps immigrants from the Kattegat) gradually abandoned their habit of spawning in the autumn in favor of spawning in the spring, initially perhaps in salt water, then in the brackish water of the Schlei. The continued influence of this new environment on the young brood eventually broke the strength of heredity and led to the development of form B. This evolution is still in progress, and based on the table above, has now reached the following stage:

1. Thirty-six percent[1] of the total have changed their way of life completely; they spawn in spring in brackish water, and have assumed form B.

2. Another 26.4 % have abandoned their previous behavior and become spring spawners, but their corresponding change of form is still incomplete. The majority of this group (18.4 %) have so far maintained form A intact; eight percent are intermediate between A and B.

3. Another 20.9 % have only partially altered their behavior, becoming winter or summer spawners instead of autumn spawners. The majority (11 %) have kept form A; some have assumed form B, and some have an intermediate habit.

4. Finally, there are still ca. 16 % which have remained pure autumn herring, and, with few exceptions, maintained form A.

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[1] Obviously, the percentages indicated in what follows are not claimed to be completely accurate.

The probability that form B evolved in this way is further strengthened by the improbability of all other possible explanations, which the reader can easily see.

Some reflection on the process of development which I have just described can help make our conceptions of the origin of species, which frequently are too schematic, clearer. With the usual conception of the nature of a species, it is not very difficult to conceive its transformation clearly with a few changes in our mind or on paper. It is different with the kind of species revealed by my research and that of others, a highly varied group of individuals with thousands of different morphological and behavioral types. The way in which such a species will change under the influence of environmental conditions which themselves are no less varied, can no longer be constructed mentally, but must be studied in nature. And here the investigation of the two races A and B, as well as the two species sprat and herring, shows that the process of speciation is extremely complex. A species exposed to the action of changing environmental conditions is transformed into a mixture of all kinds of forms, until eventually, from the chaotic mass of forms, a few main types emerge which should be regarded as the seeds of new species, and which, under favorable circumstances, through the cumulative effects of external conditions, will actually become new species. But every new species, in turn, is just as varied from the start as its ancestral form. Natural species exist -- however, not as incarnations of schematic diagnoses, but as living entities, which manifest their vitality through constant variation.

Finally, I should discuss an objection raised by an important critic against my hypothesis of the origin of form B from form A. Why, it may be asked, is the difference between autumn and spring herring not as great as between herring and sprat? Why does the Baltic, with its brackish inlets, not have its own species of herring instead of just a race, when according to geological findings, major changes in the environmental conditions of life have occurred over time in the North Sea and the Baltic? I can only answer, first, that the environmental changes were not sufficiently serious to elicit such divergence as exists between herring and sprat. Secondly, we must remember that in many parts of the North Sea and the Baltic, conditions prevail which are intermediate between those of Var. A in the North Sea and those of the brackish-water Baltic form, Var. B. As these intermediate conditions are equally satisfactory for the existence of herring, the extinction of intermediates is prevented. In all instances of species formation, this extinction will not occur until such intermediate environmental conditions have eventually disappeared. If they persist, it may happen that very great divergence of a character develops within a species without the species separating into new species-- i.e., into groups without any completely intermediate individuals between them, because they no longer have a common range in certain characters.

An excellent example is afforded by the varieties of domestic pigeons and other domesticated animals and plants. Character divergence among pigeon races is extraordinarily great as a result of the variety of environmental conditions to which they have been exposed during several centuries of rearing by man. This divergence-- as probably even opponents of Darwin recognize-- is greater than in many genera of Columbidae. Yet it seems as if all pigeon races are linked by completely intermediate types. This is not surprising, if we consider that the conditions needed for numerous intermediates to flourish are available. If pigeons throughout the world were reared systematically only from distinctly differentiated races, and in particular, if uncontrolled crossing of the different strains were strictly prevented, fully independent species would surely develop eventually.

Character divergence and the extinction of intermediates are two completely different processes which must be clearly differentiated. The former is induced by the influence of widely different environmental conditions on a species, and usually occurs in nature when a species which has become dominant spreads over a wide area. The latter (extinction of intermediates) results when, as it were, a gap occurs in the variety of environmental conditions to which a highly variable species is exposed.

Many advocates and critics of the transmutation theory too frequently confound these two quite different concepts. Their proper differentiation would prevent much futile controversy and render superfluous many chapters of learned discussion, such as Wigand's well known work.

Conclusion

In the introduction to Part One of my investigations concerning herring varieties, I expressed the view that the first and most important precondition for progress in the difficult question of herring races and migrations was to obtain useful descriptions of the different forms of herring.

I now regard this condition as fulfilled; for I believe that with a few changes, my method of description can be applied fruitfully in all areas. Its advantage compared to the previous way of differentiating races is that very small individual differences can be recognized and all age groups--particularly the larvae-- are considered equally. If further research is to be performed on the herring question--and I can certainly declare that it merits very thorough and conscientious research-- the first priority should be to apply my method of description, or a similar and more complete method, to more of those important local forms which have already frequently been named and discussed, but of which the true nature is still completely unknown. I have in mind especially those races which occur on the Norwegian coast and supply the great catches of the fishing industry in that region. It will be the task of our northern neighbors to acquaint us with those forms. Our own research area is the Baltic, particularly its large eastern sector. In this research, attention should be focussed chiefly on studying the larval forms.

No less important than useful descriptions are experimental studies of the type done first by WIDEGREN and then especially by H. A. MEYER. As the present study demonstrates sufficiently, one approach is not effective without the other. Only when both of these tasks have been performed satisfactorily, will it be possible to turn to studying the life cycle of this enigmatic species with any promise of success. Perhaps then it will also be possible for those researchers with more practical interests in the biology of herring to achieve their goals. This would be the greatest gain of which science can boast: It would benefit not only researchers wishing to unveil the secrets of life, but all of those for whom the sea and its treasures are an abundant, but not always inexhaustible, source of food.

Appendix I

Descriptions of Herring and its varieties *(Clupea harengus* L.), and Sprat *(Clupea sprattus* L.)

I presuppose a knowledge of the characters of the family Clupeidae and the genus Clupea. The reader is referred to GÜNTHER's "Catalogue of the fishes...". Since I myself have not performed extensive research on species other than the two which are treated in this study, GÜNTHER is still the definitive authority at the present time.

1. The species Clupea harengus L.

Fig. 1, 2, 3, 9, 10, and 13.

Vomer toothed. Number of vertebrae 51 to 58; total number of keel scales 36 to 48. Number of keel scales between head and ventrals 24 to 32 (usually 27 to 30); number of keel scales between ventrals and anus 11 to 20 (usually 13 to 15). Ventral fin with 7 to 10 rays (usually 9). The length of the base of the anal fin equals 0.076 to 0.118 x the total length (incl. caudal fin), and is usually shorter than the dorsal fin, sometimes equal or longer. Number of rays 15 to 20. The ratio of the distance from the tip of the snout (with the mouth closed) to the dorsal fin, to the total length is 1: 2.08- 2.45; for the ventrals, 1: 1.95- 2.24. Ventral fins located below the dorsal, from its origin to its last third. The ratio of the distance from the tip of the snout to the anus, to the total length is

1: 1.44-1.63. The ratio of the lateral head length (measured from the tip of the lower jaw with the mouth closed to the hindmost point of the operculum) to the total length is 1: 3.8- 5.5. The height at the back of the head equals 0.13 to 0.19 x total length. The height at the origin of the caudal fin is 0.05 to 0.09 x total length. Maximal body height is very variable depending on the maturation stage of the sex products, 0.14 to 0.23 x total length. Total length of reproductively mature individuals 180 to 360 mm.

Distribution: Baltic Sea, North Sea, English Channel, east coast of the United States, Arctic Ocean, Atlantic coast of northern Europe.

Behavior: Does not undertake long-distance migrations, but is a visitant fish in certain areas for spawning--usually coastal areas with saline or brackish water.

Herring are divided into numerous local races which, according to the current state of knowledge, can be grouped into the following three varieties or groups:

Variety A (Fig. 1)

The number of vertebrae is large (55 to 58), as are the total number of keel scales (38 to 48), the number of keel scales between head and ventrals (26 to 32), and the number between ventrals and anus (11 to 20).

The ventral fins, and, to a lesser degree, also the dorsal fin and the anus are located very far back. The base of the anal fin is short. The lateral head length is considerable, as is the height at the back of the head. The height at the origin of the caudal fin is short. The maximal size is large, up to 360 mm.

Distribution: North Sea; Kattegat; Great Belt; western Baltic. Probably also in the Sund. Numerous local races.

Behavior: Inhabits salt water, entering brackish water only in exceptional cases (Elbe herring). Spawns in autumn, winter, or spring (August to April), always in salt water. The young attain a length exceeding 60 mm before they take on the definitive herring form, and are found only in salt water.

Variety B (Fig. 2)

The number of vertebrae is small (51 to 57), as are the total number of keel scales (36 to 46), the number of keel scales between head and ventrals (24 to 31), and the number between ventrals and anus (11 to 17). The ventral fins, and, to a lesser extent, the dorsal fin and the anus are located far forward. The base of the anal fin is fairly long. The lateral head length and the height at the back of the head are short. The height at the origin of the caudal fin is considerable. Maximal size medium, seldom reaching 300 mm.

Distribution: Hitherto found only in the western Baltic.

Behavior: Stays in salt water, but always visits brackish inlets or river estuaries to spawn. Spawns in April or May, seldom late March or early June. The young do not exceed 45 mm in length before assuming the definitive herring form, and have been found hitherto only in brackish water.

Variety C (Fig. 3).

This form is still poorly known, and therefore its description will be less complete. It combines characters of forms A and B.

Number of vertebrae? Total number of keel scales medium; number between head and ventrals large, between ventrals and anus small. Ventral and dorsal fins located far back. Anus located far forward. Base of the anal fin very long, very frequently longer than the dorsal. The lateral head length and the height at the back of the head are short. The height at the origin of the caudal fin is short. Maximal size short, very seldom reaching 280 mm.

Distribution: Hitherto found at three locations very far apart: the southeastern part of the Baltic ('Strömling'?), the Norwegian coast near Bergen, and near Iceland; with local coloration at all three locations.

Behavior: Still obscure. Spawns in the Baltic, probably from the end of May until autumn, so that it is a summer spawner. Larvae and larval development unknown.

2. The species Clupea sprattus L.

Fig. 11, 12, and 14.

Vomer not toothed. Number of vertebrae 46 to 49; total number of keel scales 32 to 35. Number of keel scales between head and ventrals 20 to 24 (usually 22); number of keel scales between ventrals and anus 9 to 13 (usually 10 to 11). Ventral fin with 6 to 7 rays (usually 7). The length of the base of the anal fin equals 0.110 to 0.145 x the total length (incl. caudal fin), and is usually longer than the dorsal fin, sometimes equal or shorter. Number of rays 19 to 22. The ratio of the distance from the tip of the snout (with the mouth closed) to the dorsal fin, to the total length is 1: 2.06- 2.26; for the ventrals, 1: 2.06- 2.29. Ventral fins located slightly before or below the origin of the dorsal, or under its first third. The ratio of the distance from the tip of the snout to the anus, to the total length is 1: 1.54- 1.68. The ratio of the lateral head length (measured from the tip of the lower jaw with the mouth closed to the hindmost point of the operculum) to the total length is 1: 4.7- 5.4. The height at the back of the head equals 0.15 to 0.19 x total length. The height at the origin of the caudal fin is 0.06 to 0.09 x total length. Maximal body height is very variable depending on the maturation stage of the sex products, 0.16 to 0.25 x total length. Total length of reproductively mature individuals 120 to 150 mm.

Distribution: North Sea, Skaggerak, Kattegat, and western Baltic. Coast of Tasmania according to GÜNTHER.

Behavior: Like herring, a visitant which occasionally enters brackish water, but always spawns in salt water.

Sprat, like herring, has numerous local forms, but they are not yet adequately known. In the western Baltic there are two varieties, a spring spawner and an autumn spawner, which exhibit differences similar to those of herring varieties A and B in their body form as well as their development. A form with a very tall body height is known in the Elbe and a few other places (Cl. Schoneveldii Kr., Figure 12).

Appendix II

Remarks concerning the proper use of systematic terms, especially 'variety' and 'species'

Controversy still prevails regarding proper usage of the terms 'variety' and 'species' and most systematic terms in general, so that it is useful at any given time and on every suitable occasion to clarify opinions in this area. First, one point is certain: however these terms are defined, the difference between varieties and species is always only a matter of degree, as long as we are concerned only with form. The two comparison tables which I have given for herring vs. sprat and for herring varieties A and B are very striking proof of this assertion, insofar as they show that simple enhancement of varietal differences can lead to species. The physiological differences which have been established between varieties and species are based preferentially on different degrees of fertile crossing. Most likely also these differences are only matters of degree and, like the morphological differences, can be eliminated in the course of time. My task here is not to investigate this question; it will suffice to repeat what I have argued in greater detail in Part One (p. 64), viz., that the concepts of morphological species and genealogical species are completely independent of each other *a priori* and should never be confused. The discussion which follows applies exclusively to morphological species.

While it is quite clear that the difference between varieties and species is only a matter of degree, it is still necessary to maintain these terms in science. We not only need specific designations for the different degrees of difference between groups of individuals, which I have attempted to express numerically. For, such designations only convey an idea of the extent to which character divergence has progressed; they do not tell us whether there is an uninterrupted series of very fine morphological gradations between two groups of individuals, or whether there are gaps of varying sizes. But the need to differentiate these two situations and to designate the size of any gaps which occur is identical with the necessity of maintaining the terms 'variety', 'species', 'genus', etc. Very many different authors have rightly recognized this major obligation of systematists and called it to the attention of those who regard all our systematic categories as merely subjective abstractions of the human mind. It can not be repeated too often that this outlook is completely wrong. Certainly, systematic terms like 'variety', 'species', etc. are purely subjective, but if they are properly defined, they need not, and should not, be any more subjective than any other definitions. But what is the proper definition of these terms? No new answer to this question has been given, although the old criterion of correspondence or non-correspondence in the most important characters has

been so badly shaken that Darwinians, at least, have rejected it as useless. My new method of systematic description makes possible at least a partial solution to the problem, and we may hope that it will help direct us toward the complete solution. For, using this approach, we can establish three basic systematic definitions, and differentiate them clearly. Before presenting these three new definitions, I should point out that the value of any systematic definition depends, of course, on how many individuals have been investigated, and how many of their characters have been examined. In particular, it should be emphasized that any single individual which comes to be examined can probably be classed in an already well defined species, variety, etc., but that a new species (or varietal, etc.) concept can never be defined for that individual. All species in our manuals which are based on a single individual are devoid of systematic value, however striking the characters of the animal may be. An individual can only be described, not systematized; for, all systematic concepts are collective, so that at least two individuals must be grouped together. Researchers who seek to express the manifold variety of forms in nature by citing the total number of species hitherto described are actually using a faulty argument. If they were to verify all of these strikingly numerous 'species' by a rational method, probably their number would be reduced so sharply that it would no longer be at all impressive, without the variety of forms which actually exists being diminished in the least. To express this actual variety properly, it is sufficient to research a single species from every angle and present a concrete description of the differences among individuals belonging to that species.

I shall now proceed to define my three basic concepts. They result from the following simple reflection.

As we know well from Chapter Four of this treatise, when investigating and comparing two groups of individuals, one should always differentiate between the common range of variation of both groups and the exclusive range of each individual group. Now, obviously there are three possibilities:

1. There is a common range of both groups in all characters.

2. There is a common range only in some characters, and not in others.

3. There is no common range in any characters.

This yields three basic systematic concepts which I do not wish to name at the present time, since none of the terms hitherto used is suitable.

Concept 1 comprises groups of individuals like Var. A and Var. B of Clupea harengus, so that it is almost equivalent to the old term 'variety'. As soon as two groups of individuals exceed the limits of this concept, they actually become what we currently describe as different species; i.e., every member of one group can be reliably differentiated from every member of the other.

However, concept 2 not only includes what are now called species, but is much more comprehensive. For, it is possible for such different groups of individuals as, e.g., many herring, carp, and pike to have a common range of variation in some characters, such as the location of the dorsal fin, which all these fishes have. Hence, concept 2 must be subdivided. The same applies to concept 3, which is roughly equivalent to what we designate as classes, cladi (branches), and kingdoms.

In order to subdivide basic concepts 2 and 3, it is unavoidable that we must consider the developmental history of the individual; indeed, this has already long been recognized as indispensable also for the conventional differentiation of higher systematic categories. For example, it may happen that one of two groups has an organ which is absent in the other. Now, there are two possibilities: The organ which is lacking in one group may still be present in the juvenile stage, i.e., before the individual attains its permanent body form, and disappear only in the adult. Groups of this kind are more similar to each other than those in which the organ in question is already absent before the permanent body form is attained.

This difference is so important that it should be expressed by two different designations.

The following exposition is a modest attempt to subdivide my three basic systematic concepts so as to form a complete series of systematic categories. It will offer the advantage, compared with the system currently used, that all the categories are based on the same principle, and that they form a system which can very justly be described as synthetic.

Definitions for a synthetic system of nature

I. There is a common range of variation in all the characters of two or more groups under comparison; i.e., there is no character in which no individual of one group is completely similar to any individual of the other.

a. Neither group has an exclusive range of variation; i.e., every individual falls in the common range in all of its characters, and is completely intermediate:

α. The different combinations of all characters occur in equal percentages in both groups. Such groups are identical and belong to the same race (subvariety)[1]....................................1

β. The different combinations of all characters occur in unequal percentages in the two groups.

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[1] (Translator's note:) In the main text, the author used Rasse ('race') as synonymous with 'variety', and I have also sometimes translated it as 'variety'.

Such groups are different races and belong to the same variety....................................2

b. One or both group(s) have an exclusive range of variation. These groups are different varieties and belong to the same subspecies.........................3

II. Two or more groups have a common range in one or more qualities, but not in others; i.e., there are qualities in which no individual of one group resembles any of the other group.

a. All organs of one group are present in the other group.

α. There are individuals which fall within the common range in every character which has a common range, and are 'incompletely intermediate'. Groups of this kind are different subspecies and belong to the same species............................4

β. There are no such individuals. The groups are different species and belong to the same genus..5

b. One or more organs of one group are absent in the other group.

γ. The organs which are present in one group and absent in the other, are absent (or present) only when the other organs have already attained their permanent form. Such groups are different genera, and belong to the same family..................6

δ. One or more of these organs are present (or absent) already before the other organs have attained their permanent form. These groups are different families, and belong to the same order..7

ε. All these organs are already present (or absent) before the other organs have attained their permanent form. These groups are different orders, and belong to the same class...........8

III. Two or more groups do not have a common range of variation in any quality; i.e., there is no character in which an individual of one group is similar to one from the other group.

a. One or more organ(s) of one group occur in the other group also.

α. The positions of these organs in relation to one another, and their development are the same. Such groups are different classes, and belong to the same branch (cladus).......................9

β. The positions of these organs in relation to one another, and their development are different. These groups are different branches, and belong to the same kingdom............................ 10

b. No organ of one group is found in the other.

γ. The ultimate structural elements are similar, or arise from the same basic form (cell). Such groups are different kingdoms, and belong to the same system....................................11

δ. The ultimate structural elements are different, and do not arise from the same basic form. These groups are different systems, and together they form nature....................................12

Since I have used the old names again to designate my systematic concepts in the preceding exposition, the question arises to what extent my new definitions coincide with the usual understanding of these terms. Although it is clear that the use of these terms in our systematic manuals is extremely arbitrary, it would still be completely wrong to deny that several of them are, on the whole, well founded in nature. Hence, anyone who wishes to offer an improvement has the unavoidable obligation of reconciling his new terminology as much as possible with the old terminology. Overall, I believe that I have met this obligation. As far as the concept of 'species' is concerned, I differentiate a lower rank, which I call 'subspecies', and a higher rank which keeps the old name. Probably my 'subspecies' is not completely identical with that term as defined by previous authors. Of course, it is difficult to determine exactly what is the current meaning, since hardly any systematic term has been used as arbitrarily as 'subspecies'. With my definition, its meaning is fixed as clearly as any systematic definitions can be at the present time.

The only previous definition for 'genus' was a number of species linked by common qualities and more or less distinctly differentiated from other species. My completely new definition draws a sharper distinction between genus and species, since two groups which rank as different species have all the same organs, but two genera do not, since at least one organ is absent in one genus.[1] I hope that more exact systematic research on extensive material will show that my distinction is useful, and also that it expresses more precisely the difference which previous systematists 'discretely' adumbrated.

Whether the same applies to my definitions of 'family', 'order', etc., may remain an open question.

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[1] The reader may have noticed that according to my definition of a genus, Clupea harengus and Clupea sprattus are actually two different genera, insofar as the dentition of the vomer is absent in the latter. If I had examined this character in numerous individuals of both groups and found that this difference is constant, I would not hesitate for a moment to establish a new generic name. But since this has not been done, I shall leave the old name for the present.

Table I. Herring from Kiel, Eckernförde and the Schlei, grouped into var. a and b

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- date 5- place 6- remarks 7- sex and maturation stage 8- February 9- March 10- January 11- June 12- May 13- July 14, 15, 16, 17- see explanatory note 2 below 18- fully developed herring 19- end of larval stage 20- transitional stage 21- end of transitional stage 22- keel scales 23- maturation stage *Fat content categories:* 24- very high 25- low 26- exceptional 27- moderate 28- none 29- high 30- definitely high 31- considerable

Explanatory notes

1. In both varieties, the ends of the larval, transitional and juvenile stages are marked by a line across the last column, with a corresponding remark. All individuals listed before the line are larvae (or transitional or juvenile), unless otherwise stated.

2. Stages of development of the ventral fins are designated as follows: (1) Ventr. [or V.] fehlt = ventral fin absent (2) V[entr.] angelegt = ventral fin present, but only with embryonal rays (3) V[entr.] entw. = already with an unspecified number of definitive fin rays (4) 'Ventr. 6, 7, 8, etc.' indicates the number of rays. --'Ventr. 4-5' means that one ventral fin has four rays, and the other has five.

3. Individuals from 180 to 320 mm total length marked with an asterisk are var. a spring herring on the left page and var. b autumn herring on the right. The unmarked individuals are var. a autumn herring on the left and var. b spring herring on the right.

4. Individuals from 60 to 180 mm marked with an asterisk are var. B on the left, var. A on the right; those marked with a dagger are intermediates. The unmarked individuals are var. A on the left and var. B on the right.

5. Individuals on the left with total lengths below 60 mm marked with an asterisk are var. a spring herring.

var. a

Totallänge ① mm	Seitliche Kopflänge ②	Formel ③ der Höhen, Längen und Kielschuppen				Datum ④	Ort ⑤	Bemerkungen ⑥
27.5	e		7	-1 b -I o		29. Nov. 77	Kiel	V. angelegt ⑮
.7			8	-3 -V		25. April 75	Eckernförde	V. fehlt ⑯
28.0				-2 -III		2. Februar 76	„	
				-2 c -II		27. Nov. 77	Kiel	
.8	f		7	-2 g -II o		29. Nov. 77	„	V. angelegt
29.0	g		8	-3 -II		30. April 75	Eckernförde	
	g		8	-3 -III		„	„	
.5	e			-1 b -I o		29. Nov. 77	Kiel	V. angelegt
30.0				-1 -II		2. Februar 76	Eckernförde	
31.0				-3 d -I		4. Dec. 77	Kiel	V. 4—5 ⑭
			8	-2 b -II o		„	„	V. 3—4
.1	g		8 - f - II	-1 d -II A		„	„	V. angelegt
32.0	h		7	-3 c -II -A		„	„	V. 3—4
.2	g		8	-2 -IV		30. April 75	Eckernförde	
.4	e		7	-2 a -III		4. Dec. 77	Kiel	V. 5—6
32.5	f		8 - e - I	-2 d -I o		18. März 78	„	V. angelegt
.7	h			-2 -III		30. April 75	Eckernförde	
33.0	e		7	-1 b o o		4. Dec. 77	Kiel	V. 5—6
.4				-1 d -II		15. Januar 77	Eckernförde	
.5	d		8 - e - II	-2 c -II o		18. März 78	Kiel	V. angelegt
34.0	g			-3 -III		15. Januar 77	Eckernförde	V. angelegt
.4	f		8 - f - I	-1 c -II o		18. März 78	Kiel	V. 6
.5			8 - I	-1 d -I		„	„	V. angelegt
35.0								
36.5	f	1	8 - e - II	-1 d o A		„	„	V. 5—6
37.0	k		8	-2 d -II		25. April 75	Eckernförde	
.1	f	1	8 - e	-2 d -I A		18. März 78	Kiel	V. 5
.7	f	1	8 - e - I	-1 c -I o		„	„	V. 6
38.0	g		8	-1 d -II		25. April 75	Eckernförde	
	f		8	-1 b -II		„	„	
	e		8 - e - I	-1 d -I		18. März 78	Kiel	
39.0	e		7	-2 b -I B		2. Februar 76	Eckernförde	V. 9
.2	b	1	4 o I	1 a II B		9. August 78	Kiel	ausgebildeter Hering ⑱
.5	c	1	8 - c - I	-1 c -I A		18. März 78	„	V. 7
.6	f	1	8 - e - I	-1 c o o		„	„	V. 7—8
.7	e	1	8 - e - I	-1 b -I -A		„	„	V. 7
40.0	h		8	-1 c -II		11. April 75	Eckernförde	V. 7
				-2 c -I		25. April 75	„	
		1	8 - I	-2 b -I A		18. März 78	Kiel	V. 7
.2	f	1	8 - e - I	-2 c o o		„	„	V. 8
.6	e	1	7 - e - I	-2 e -I A		„	„	V. 8

var. b

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Bemerkungen
21.0				−2		10. Juni 76	Schlei	V. fehlt
23.0				−2		„ ⑪	„	V. fehlt
26.5				−1 d 0		„ ⑫	„	V. fehlt
27.0	e		7	−1 d −II		15. Mai 74	„	V. angelegt
27.7				−2		10. Juni 76	„	V. 7
.8				−1 c −III		15. Mai 74	„	V. entw. ⑰
28.0				−2 d 0		10. Juni 76	„	V. 6
29.0	e		8	−1 c −I		15. Mai 74	„	V. entw.
	d			−1 b −II		23. Juni 74	„	
				−3 d		„	„	
31.0				−2 d −I		10. Juni 76	„	V. entw.
								Ende des Larvenstadium. ⑲
.5	c		6	0 b I		23. Juni 74	„	V. 8—9
32.0			5	1 c I		„	„	V. 9
35.0	c		5	1 b I		23. Juni 74	„	
37.0				1 c		„	„	
	a	1	4 a 1	1 b II C	b II. β	20. August 78	„	ausgebildeter Hering
	a	1	3 b 1	1 b II B	c III. γ	„	„	„ „
.8	a	1	3 a 1	1 b I B	II.	„	„	„ „
38.0								
38.1				1 b I		23. Juni 74	„	
.6				1 b I		„	„	
39.0								
.4			3	1 c 0		„	„	
40.0								

var. a

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Bemerkungen
41.3			7	–1 b –I		25. April 75	Eckernförde	V. 7
.3	c		7	–1 a –I A		30. April 75	"	V. 8–9
.4	e	1	7 – e o	–1 c o o		18. März 78	Kiel	V. 9
* .5	e	1	7 – e o	–1 b o o		"	"	V. 9
* .7	a	1	3 b II	1 a II B		20. August 78	Schlei	ausgebildeter Hering.
42.0	e		7	–1 a –II B		30. April 75	Eckernförde	V. 9
.5	d		6	–1 a –I B		"	"	V. 9
43.5	d	1	6 – c I	–1 c I A		18. März 78	Kiel	V. 9
43.6	e	1	7 – d o	–1 c –I o		"	"	V. 9
44.0	d		6	o a o		25. April 75	Eckernförde	V. 8–9
	c		6	–1 b o C		30. April 75	"	V. 9
	b		5	1 b I		25. April 75	"	Uebergangsstadium ⑳
* .2	c		7	–1 a –I		"	"	V. 6
* .3	a			2 a II		9. August 78	Kiel	ausgebildeter Hering
*45.2		1	3 c I	2 a I B	c II. γ	20. August 78	Schlei	" "
* .6	a		3 c I	2 a II		9. August 78	Kiel	" "
*46.8	a	1	b I	2 a II B		"	"	" "
47.0	c			o c II		15. Januar 77 ㉒	Eckernförde	V. 9
	b		4	1 a II C		26. Juli 75	Kiel	Ende des Larvenstadiums
* .3		1	3 b II	2 a II B		9. August 78	"	ausgebildeter Hering
* .8	a	1	2 b II	1 a II B		"	"	" "
*48.5	a	1	3 b II	1 a II A	c II. γ	20. August 78	Schlei	" "
* .7	a	1	3 b I	2 a II B	a III. β	9. August 78	Kiel	" "
* .8	b	1	2 b II	2 a II B		"	"	" "
49.9	b		4	1 a I C		28. Juni 75	Eckernförde	
50.0	b		5	1 b I		"	"	
*		1	2 b II	1 a I B		9. August 78	Kiel	" "
*51.0				1 b I C		28. Juni 75	Eckernförde	
*		1	2 c II	1 o I C	II.	24. Octbr. 77	Schlei	" "
* .2	a	1	3 c II	1 a I A	c II. γ	"	"	" "
*55.0	a	1	3 c II	1 a I A	II.	26. Novbr. 74	"	" "
56.0	b		4	2 b II C		28. Juni 75	Eckernförde	
.3				3 b II C		"	"	
*58.0	a	1	3 c II	1 b II B	III.	26. Novbr. 74	Schlei	" "
* .5	a	2	2 c II	1 b II C	a II. β	26. August 75	Kiel	" "
60.0	b		4	1 b II C		28. Juni 75	Eckernförde	
61.1	a	1	2 b II	2 a II B	a	17. August 78	Kiel	Ende des Uebergangsstad.

㉑

var. b

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Bemerkungen
41.5	b		4	2 b II		23. Juni 74	Schlei	
42.0				2		"	"	
.2	a	I	3 b II	2 b II B		9. August 78	Kiel	ausgebildeter Hering.
43.2				1 b		23. Juni 74	Schlei	
44.0	a	I	3 a II	2 b II A		9. August 78	Kiel	Ende des Uebergangsstad.
.2	a	I	2 c II	2 b II B		"	"	
.2	a	I	3 b II	1 b II A		"	"	
.6	a	I	3 b II	2 b II B	c II. β	"	Schlei	
45.2	a	I	3 b I	1 b II A	c III. γ	20. August 78	"	
.5	a		3 b II	1 b II A		9. August 78	Kiel	
46.2	a	I	2 b II	2 a III B		"	"	
.5	a	I	3 b II	1 b II B	b II. β	20. August 78	Schlei	
50.2	a		2 b II	2 b I B	b III. γ	9. August 78	Kiel	
51.5	b		2 b III	2 c III	II.	27. Juli 75	Schlei	
	a	I	3 c II	2 b III B	c III. γ	20. August 78	"	
52.3				2 b		18. Juli 74	"	
53.0	a	I	2 c II	2 a III B	II.	9. August 74	"	
				3 b		18. Juli 74	"	
.8	a	I	2 c II	2 b II A	b III. γ	17. August 78	Kiel	
54.0	b	I	3 b II	3 c III C	II.	20. August 74	Schlei	
55.0	a		3 b II	2 b III B	III.	26. Nov. 74	"	
	b		3 b			"	"	
.3	a	I	3 c I	2 b II B	c II. γ	20. August 78	"	
.6	a	I	2 c III	2 b II B	b II. β	9. August 74	"	
.6	b	I	2 b II	2 c II C	c II. γ	"	"	
56.0			3 b II	3 c III	II.	27. Juli 75	"	
	a	I	2 b II	2 a III B	III.	18. Juli 74	"	
56.7	b	I	2 b II	2 b III B	c III. γ			
57.0	b	I	2 c III	3 b III B	II.	6. Sept. 74	"	
58.0	a	I	3 a II	2 a III A	II.	26. Nov. 74	"	
.3	b		2 b II	3 b II	III.	27. Juli 75	"	
59.0	b	I	2 c III	3 b III B	III.	18. Juli 74	"	
61.0				3 b		"	"	
† .2	b		3 b II	2 a III	b III. β	17. August 78	Kiel	
.9	b	I	2 c III	3 c III B	III.	"	"	
62.0	b	I	2 c III	2 b II B	II.	24. Sept. 74	Schlei	

var. a

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Bemerkungen
63.0				1 a				
.6	a		2 c	1 a I		9. August 78	Kiel	
65.5	a	1	2 c II	2 a II B	III.	24. Decbr. 74	Schlei	
66.0	a	1	3 b II	2 a II B		20. Novbr. 75	Kiel	
† .5	b	1	2 c III	2 a II B	b III.* β	9. August 74	Schlei	
.8	a	1	2 b II	2 a II B	a	17. August 78	Kiel	
67.0	a	1	2 c II	2 a II B		24. Septbr. 74	Schlei	
†68.8	b	1	2 c III	2 a II B		9. August 78	Kiel	
69.5	b	1	2 b II	2 a II B		„	„	
71.8				1 b II A		6. März 75	Eckernförde	
72.0	b	1	3 b II	2 a II B	III.	24. Decbr. 74	Schlei	
73.5	b	1	3 b I	2 a II C		4. Juli 78	Kiel	
76.3	a	1	2 c II	2 a II B		9. August 78	„	
78.0	a	1	2 b II	2 a II A	b II. β	28. Januar 78	Schlei	
79.0	b	1	2 b II	1 b II A	a II. α	20. Novbr. 75	Kiel	
81.0	a	1	3 b II	1 b II A		„	„	

var. b

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Bemerkungen
62.7	b	1	2 c III	2 c III C	c II. γ	9. August 74	Schlei	
*63.0	a	1	3 c II	1 a III B	III.	26. Nov. 74	„	
·3	b	1	2 c III	2 b III B	c II. γ	9. August 74	„	
·3	a	1	3 c II	2 b II A	c II. β	20. August 78	„	
* ·7	a	1	3 b II	3 a III B	II.	20. Jauuar 78	„	
64.1	b	1	3 b II	1 c III B	b III. γ	17. Sept. 77	„	
65.0	b	1	3 b II	3 c III B	II.	9. August 74	„	
66.1	b	1	2 c II	2 b III B	c II. γ	„	„	
*67.0	a	1	2 c II	2 b III C		17. Sept. 77	„	
*	a		2 c II	2 b III A		9. August 74	„	
·5	a	2	2 b II	3 c III C		17. Sept. 77	„	
68.5	a	1	2 b II	3 b II C		„	„	
* ·5	a	1	2 c II	2 b II B	II.	20. August 74	„	
* ·5	a	1	3 b II	2 b II B		17. August 78	Kiel	
68.9	b	2	2 b II	3 c III C		17. Sept. 77	Schlei	
†69.0	a	1	2 c II	3 b III B	III.	24. Sept. 74	„	
·5	a	1	3 b II	2 b III B	c II. γ	20. Januar 78	„	
70.5	b	1	2 b II	2 b III B		17. August 78	Kiel	
71.0	a	1	2 c III	3 b II B	III.	24. Sept. 74	Schlei	
.2	b	1	2 c II	2 c III C		9. August 78	Kiel	
* .2	a	1	3 b II	2 b II B	b	20. Januar 78	Schlei	
.2	b	1	3 b I	3 b III C	c III. γ	„	„	
.4	a	1	2 c III	3 b III A	b II. β	„	„	
.6	a	1	3 b II	3 b III B	b II. β	„	„	
*72.0	a	1	3 a II	2 b II B		„	„	
* .2	b	1	2 c II	2 b II B	b II. β	9. August 74	„	
* ·3	a	1	3 b II	2 b II B		17. Sept. 77	„	
	a	1	2 c II	2 c IV C	b III. γ	17. August 78	Kiel	
†	a	1	2 b II	2 c II B	II.	6. März 75	Eckernförde	
73.0	a	1	3 b I	3 b III B	c II. β	20. Januar 78	Schlei	
*	a	1	2 c II	2 b II B	III.	26. Nov. 74	„	
* ·5	a	1	2 c II	2 b II C	a I. α	30. August 75	Kiel	
.6	a	1	2 c II	3 b III C	c II. γ	20. Januar 78	Schlei	
74.0	b	1	2 b II	2 b III B	c II. γ	„	„	
*	a	2	2 c I	2 b II C	III.	24. Dec. 74	„	
·5	a	1	2 c II	2 b III C	c II. γ	9. August 74	„	
† ·5	a		3 b II	2 b III	II.	17. August 78	Kiel	
75.0	a	1	3 b I	2 b III B	c II. γ	20. Januar 78	Schlei	
	b	1	2 b III	2 c III A	III.	27. Juli 75	„	
* ·7	a	1	2 c II	2 b II B		9. August 78	Kiel	
76.0	a	1	1 c III	2 b II A		24. Sept. 74	Schlei	
.8	b	1	3 a II	3 b II B	III.	15. Sept. 74	Eckernförde	
77.6	b	1	2 b II	2 b II B	c II. γ	20. Januar 78	Schlei	
78.0	b	1	2 c III	3 b III B	II.	6. Sept. 74	„	
†	b	1	3 b II	2 b II B	b II. β	17. August 78	Kiel	
.2	b	1	2 c II	3 b II A	c II. γ	28. Januar 78	Schlei	
	b	1	II	2 a III B		15. Sept. 74	Eckernförde	
* ·5	a	1	2 b I	2 b II B		15. Februar 76	„	
79.0	b	1	3 b I	1 c II A	II.	26. Nov. 74	Schlei	
*	a	1	2 b II	2 b II A	II.	9. August 78	Kiel	
	a	1	2 c III	2 c III B	II.	15. Sept. 74	Eckernförde	
	b	1	2 b II	3 c IV B	d III. δ	März 76	Kiel	12 + 24 Kielschuppen. V. 8
80.0	b		2 b II	3 c III	III.	27. Juli 75	Schlei	㉑
	b	1	2 b III	3 b III B	III.	24. Sept. 74	„	
*81.5	a	1	2 b II	2 b II A	c II. β	20. Januar 78	„	

var. a

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Bemerkungen
85.0	b	1	2 b ll	2 a ll A	b lll. γ	17. August 78	Kiel	
87.5	a	1	1 c ll	2 a ll B	ll.	26. August 75	"	
89.0	a	1	2 c ll	2 a ll B	ll.	"	"	
96.0	b		3 b	2 a ll	ll.	12. Februar 75	Eckernförde	
98.4	a	1	2 c ll	1 a ll B	o l. o	17. August 78	Kiel	
102,0	a	1	2 b ll	2 a ll B		6. März 75	Eckernförde	
†115.0	b	1	2	2 a ll C		23. Juni 74	Schlei	

var. b

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Bemerkungen
*82.0	b	1	2 b II	2 b II C	II.	9. August 74	Schlei	
	b		2 c III	2 b III B	II.	24. Sept. 74	"	
.5	b	1	2 b II	3 b II C	c II. γ	9. August 74	"	
	b	1	3 b II	2 b III B	I.	26. August 75	Kiel	
†83.0	b	1	2 b II	2 b II A		17. Sept. 77	Schlei	
† .4	a	2	2 c III	2 b II B	II.	26. August 75	Kiel	
	b	2	2 b II	2 c III C	III.	24. Sept. 74	Schlei	
84.0	b	1	2 b II	2 c III B	a II. β	17. August 78	Kiel	
.2	b	1	3 b I	3 b III B	b III. γ	20. Januar 78	Schlei	
† .5	a	1	2 c III	2 b II B	b II. β	9. August 78	Kiel	
.5	b	1	2 c II	2 b III B	III.	26. Nov. 74	Schlei	
85.5				2 b III		31. März 75	Eckernförde	
.5				2 c III C		6. März 75	"	
	b	1	2 b II	2 c III B	II.	1. October 74	"	
	b		2 b	2 b II	II.	9. August 78	Kiel	
86.0	a	1	3 b I	3 b III B		März 76	Eckernförde	
.2	b	1	2 b II	2 b III B	b II. β	17. August 78	Kiel	
	b	1	2 c II	1 c III B		"	"	
	b	1	2 c II	3 b II B	II.	24. Sept. 74	Schlei	
87.2	b	1	2 c II	2 b III B	b II. β	17. August 78	Kiel	
.5	b	1	2 b II	2 b III C	III.	1. October 74	Eckernförde	
89.7	b	1	3 b II	2 c II A		17. Sept. 77	Schlei	
90.2	a	2	3 b III	2 b III B	II.	26. August 75	Kiel	
92.0	b	1	2 b II	3 b III B	III.	1. October 74	Eckernförde	
†93.0	b	1	2 b II	2 b II C	b I α	4. Juli 78	Kiel	
	b	1	3 b II	2 b II B	II.	26. Nov. 74	Schlei	
.6	b	1	2 c II	3 b III B	II.	26. August 75	Kiel	
94.1	b	1	2 b I	3 b II C	b II. β	20. Januar 78	Schlei	
.5	b	1	2 b II	2 c III B		20. Nov. 75	Kiel	
†95.5	b	1	2 b II	2 b II A		24. Dec. 74	Schlei	
96.5	b	2	2 b II	3 c III C		Februar 76	Eckernförde	
†97.0	b	1	2 b II	2 b II B	II.	26. Nov. 74	Schlei	
98.7	b	1	2 b II	3 c III B		20. Nov. 75	Kiel	
100.7	b	1	b II	4 b III C		4. Juli 78	"	
†102.3	b	1	b II	2 b II B	III.	"	"	
108.0	b	1	1	3 c III A		23. Juni 74	Schlei	
.5	b	1	3 b II	2 b II B	II.	4. Juli 78	Kiel	
.8	b	2	3 b II	2 b II C	b II. β	2. Nov. 78	"	
109.0	c	1	3 b I	2 b III B	II.	26. Nov. 74	Schlei	
	b	1	2 b II	3 b III B	b II. β	2. Nov. 78	Kiel	
.2	b	1	3 a II	2 c III B		20. Nov. 75	"	
110.2	b	2	3 a II	2 b II B	I.	2. Nov. 78	"	
.5	b	2	2 a II	2 b III C		20. Nov. 75	"	
112.0		1	b II	2 b III B	II.	19. Juli 75	Eckernförde	
113.0	b	1	2 b I	3 b III C	a III. β	20. Januar 78	Schlei	
.2	b	1	3 a II	2 b II B	c III. γ	4. Juli 78	Kiel	
† .3	b	1	3 a I	2 b II B	a II. β	"	"	
.8	b	1	3 b II	3 c III B		20. Nov. 75	"	
114.0	b	2	3 b II	3 b II B		19. Juli 75	Eckernförde	
.5	b	1	2 b II	2 c II B	b II. β	2. Nov. 78	Kiel	
*115.0	b	1	2 b II	2 b II B	a II. β	"	"	
.5	b	1	2 b II	2 b III B	b II. β	20. Januar 78	Schlei	
†116.0	b	1	2 b II	2 b II B	b III. β	4. Juli 78	Kiel	
.6	b	1	3 a II	2 b III B	a II. β	2. Nov. 78	"	
*117.0	b	1	3 b II	2 b II B	a II. β	"	"	
.6	b	1	2 b II	3 b II B	II.	20. Januar 78	Schlei	
118.0	b	1	1	2 b II B		23. Juni 74	"	
121.0	b	1	1	3 b III A		"	"	
†	b	1	3 b II	2 b II B	b II. β	4. Juli 78	Kiel	

var. a

llänge m	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
.5	b	1	2 b II	2 a I B	a III. β	19. Octbr. 78	Kiel				
	b	1	2 b II	2 a II B	b II. β	„	„				Reifestadium I sehr fett ㉓
	b		3	2 a		6. März 76	„				
	b		2	2 a		19. Octbr. 75	„				
	b	1	3 a I	2 a II A	a III. β	19. Octbr. 78	„				
	b		2	3 a		6. Novbr. 75	„	♀	I	–	sehr fett ㉔
	b		2	3 a		19. Octbr. 75	„				
				1 b II A	b II. β	4. Mai 78	Schlei	♀	VI		wenig fett ㉕
			3 a I	2 a II C	III.	16. März 78	Kiel		I		sehr fett

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
	b	1	2 b II	3 b III C	a II. β	2. Nov. 78	Kiel				
122.0	b	1	2	2 c III B		23. Juni 74	Schlei				
	b	1	2 b II	3 b III B	c III. γ	2. Nov. 78	Kiel				
123.7	b	2	2 b II	3 c III B		10. Juli 78	"				
*124.0	b	1	2 b II	3 b II B	a II. α	20. Januar 78	Schlei				
*126.0	b	1	2 b II	2 b II B	a II. α	2. Nov. 78	Kiel				
130.8	b	1	2 b II	2 b III B	b II. β	"	"				
133.0	b	2	2 b II	3 c III B		10. Juli 78.	"				
135.0	b	1	2 b II	3 c II A	II.	26. Nov. 74	Schlei				
.6	b	2	2 b III	2 b II C	I.	19 October 78	Kiel				
.7	b	2	2 b III	2 b III C	b II. β	"	"				
†137.7	b	1	3 b II	3 b II A	b II. β	20. Januar 78	Schlei				
140.5	b	1	2 b II	3 b II B	b II. β	4. Juli 78	Kiel				
*142.0	a	1	2 b I	2 b III A		10. Juli 78	"				
.2	b	1	2 b I	2 b III B		"	"				
*147.0	b	1	3 b II	2 a III B	a II. α	23. März 78	"				
148.5	b		3	2 c		19. October 75	"				
154.7	b	1	3 b II	2 b II C	b II. β	19. October 78	"				
159.0	b	1	2 b II	2 c II B	b I. β	"	"				
160.8	b	1	3 a I	3 c III B	b II. β	23. März 78	"				
162.0	b	2	3 a II	2 b III B	b III. β	19. October 78	"				Reifestadium I. sehr fett
163.0	b	1	2 b II	2 b II C	b II. β	"	"				
.2	b	1	2 b II	2 b III B	b II. β	"	"				
166.0	b	1	2 b II	3 b II B	b II. β	"	"				
† .5	b	1	3 a II	3 b II B	a I. o	23. März 78	"				
.7	b	1	3 a	2 b II C	a II. β	19. October 78	"				
168.6	b	1	2 a II	2 b II B	b III. β	"	"				
172.0	a	2	3 a II	2 c III C	b II. β	23. März 78	"				
	b	1	3 a I	2 b III B	a III. β	"	"				
		1	3 a I	3 c III B	III.	"	"				
	c	1	2 a II	2 b III C	b II. β	19. October 78	"				
*173.5	b	1	3 a II	2 b II A	b II. β	23. März 78	"				
*174.0	c	1	2 b II	2 b II B	a I. α	19. October 78	"				
† .2	b	2	3 a II	2 b II C	a II. α	"	"				
175.0	c	1	2 a II	3 c III B	b III. β	"	"				
.4	b	1	2 b II	2 c II B	b II. β	"	"				
176.7	b	1	2 a I	3 b II B	b III. β	"	"				
• .8	b	1	3 a II	3 b II B	a II. α	23. März 78	"				
177.0	b		2	2 b		19 October 75	"				
.2	b	1	3 a I	2 b II B	b II. β	19. October 78	"				
178.0	b	1	2	2 b		19. October 75	"				
	c		2	2 c		"	"				
180.6			3 a I	2 b II B	I.	16. März 78	"	♂	I		sehr fett
181.0	c	1	2 a I	2 c II A	b II. β	19. October 78	"		I		" "
182.0	b	1	3 a I	3 b II B	II.	October 76	Eckernförde				
183.5	a	1	2 b II	3 b II C	III.	5. Juli 78	Kiel	♀	I—II		" "
184.0	a	1	3 a I	2 c III B	II.	October 76	Eckernförde				
185.5			3 a I	2 b II		16. März 76	Kiel	♀	I		" "
.5	b	1	3 a II	2 b II B	b III. β	19. October 78	"		I		" "
187.0	c	1	2 a I	2 b II B	b II. β	"	"		II		" "
.5	b	1	a II	2 b II C		5. Juli 78	"		I		auss. fett ㉖
188.5	b	1	3 a II	2 b III B	b II. β	3. Dec. 77	"	♀	I—II	55	" "
189.1	c	1	2 b II	2 b II C		5. Juli 78.	"	♂	I		" "
190.0	c	1	3 a I	3 c III B	b II. β	19. October 78	"		I		sehr fett
191.0	b	1	3 a II	2 b III C	III.	5. Nov. 77	"			57	
				2 b II C	b III. β	4. Mai 78	Schlei	♀	V		mässig fett. ㉗
192.2	c	1	2 a II	2 b II A		9. Juli 78	Kiel		I		auss. fett

var. a

Totallänge mm	Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
•196.0				2 a I B	II.	4. Mai 78	Schlei	♀	VII—II		mässig fett
• .5			a II	2 a II A	b II. β	16. Mai 78	"	♂	II	56	wenig Fett
.6	b	1	3 b II	2 a II B	b III. β	19. Octbr. 78	Kiel		I		sehr fett
•199.0			a I	2 b I o	b III. γ	16. Mai 78	Schlei	♀	VI	55	mässig fett
200.0	b	1	2 a II	2 a III B	a III. β	6. Novbr. 77	Kiel				
	b		3	2 a		29. Octbr. 75	"	♂	I—II		wenig Fett
.5				2 a I B	b II. β	4. Mai 78	Schlei	♀	III—IV	55	mässig fett
•201.5				2 b I B	c III. γ	"	"	♀	V	55	ohne Fett ㉘
202.0	b	1	3 a I	2 a II C	b III. γ	11. Novbr. 77	Kiel	♀	V		sehr fett
204.0	c		3	2 a		19. Octbr. 75	"	♀	II		
•	c		2	2 a		10. März 76	"	♀	IV		ziemlich fett ㉙
• .5				2 a II B	b III. γ	4. Mai 78	Schlei	♀	VI	56	wenig Fett
•205.0	c	1	3 a II	2 a II B	III.	20. August 78	Kiel		I		sehr fett
•207.5				2 b I B	III.	18. März 78	Schlei	♂	IV		wenig Fett
•209.0				1 b II C	b III. β	4. Mai 78	"	♀	VI		wenig Fett
210.0	b	1	2 b II	1 b II B	II.	29. Novbr. 77	Kiel	♀	V		ohne Fett

var. e

Totallänge mm	Seitliche Kopfflände	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
193.0			a II	2 b II B	b II. β	16. Mai 78	Schlei	♂	VII	56	mässig fett
			b II	2 b III B	c III. γ	„	„	♀	VII	56	ohne Fett
194.2			a II	3 b II C	b III. γ	„	„	♂	VII—II	55	
.5				2 b II B	b III. γ	4. Mai 78	„	♀	VII—II	55	wenig Fett
195.0	c	1	2 a II	3 b II B	b II. β	17. August 78	Kiel	♂	I—II	55	sehr fett
196.0	c	1	3 a I	3 b III B	b II. β	3. Dec. 77	„	♂	I—II	55	„ „
			a II	3 b II B	b III. β	16. Mai 78	Schlei	♂	VII	55	mässig fett
196.0	c		2	2 b		27. October 75	Kiel	♀	II		sehr fett
.5				2 b II C		15. März 78	„	♂	I—II		auss. fett
197.0			b I	3 b II B	b III. γ	16. Mai 78	Schlei	♂	VI	56	wenig Fett
	c	1	2 b I	2 b II B	b II. β	3. Dec. 77	Kiel	♂	III	56	sehr fett
	c	1	2 a II	2 b III B	b III. γ	„	„	♂	I—II	55	„ „
199.0			a I	2 b III B	b III. γ	16. Mai 78	Schlei	♀	VII—II	56	mässig fett
				3 c II B	b II. β	4. Mai 78	„	♀	V	55	wenig Fett
				2 b II B	III.	15. März 78	Kiel	♀	V		ohne Fett
.5				2 b II		„	„	♂	IV		wenig Fett
200.0			a II	2 b II A	b III. γ	16. Mai 78	Schlei	♀	VII—II	54	ohne Fett
				3 b III B	II.	4. Mai 78	„	♂	VII	56	wenig Fett
.5	c	1	3 a II	2 b II C	b III. γ	11. Nov. 77	Kiel	♀	III		sehr fett
.8	c	1	2 a II	2 b II B	o	14. August 78	„	♀	II	57	auss. fett
201.0	c	1	2 a I	2 b III B	a III. β	3. Dec. 77	„	♂	II—III	55	sehr fett
•	c	1	2 a II	2 c III B	a II. α	29. Nov. 77	„	♀	II		auss. fett
.2				2 b II B	b II. β	4. Mai 78	Schlei	♀	V	56	ohne Fett
.5			a I	2 b II B	b III. γ	16. Mai 78	„	♂	VI	55	„ „
			b II	3 b III B	c III. γ	„	„	♂	VII	51	„ „
			a II	2 b II A	b II. β	„	„	♀	VII	56	„ „
	c	1	2 b II	2 c II B	a II. β	17. August 78	Kiel		I—II	55	auss. fett
202.0	b	1	3 a II	2 b II B	b II. β	3. Dec. 77	„	♂	I—II	56	„ „
•				3 b II		15. März 78	„	♀	II		sehr fett
				b II		16. März 78	„	♂	III—IV		wenig Fett
			a II	2 b II B	c II. γ	16. Mai 78	Schlei	♂	VII	55	mässig fett
202.7			a I	2 b II B	b II. β	„	„	♂	VII	56	wenig Fett
203.0	c	1	3 a II	2 b II B	a II. β	3. Dec. 77	Kiel	♂	II—III	56	sehr fett
• .7				2 b II A	II.	15. Juli 78	„	♂	III—IV		„ „
•204.0	b		3	2 b		6. März 76	„	♂	II		recht fett (30)
.5	c	1	2 a II	2 c II C	b II. β	15. Juli 78	„	♂	II		sehr fett
• .5				3 b II B		15. März 78	„	♀	II—III		„ „
.5			a I	2 b II B	b II. β	16. Mai 78	Schlei	♂	VII	56	wenig Fett
205.0	c	1	3 a II	3 b II B	b II. β	3. Dec. 77	Kiel	♂	III	56	sehr fett
	c	1	2 a II	3 b II B	b II. β	„	„	♀	III	56	auss. fett
	c	1	2 a I	2 b II B	b III. γ	16. Nov. 77	„	♂	III—IV		sehr fett
				2 b II B	b II. β	4. Mai 78	Schlei	♂	IV	55	wenig Fett
206.0	c	1	3	3 c III B	III.	23. Mai 77	„	♀	VII		
				2 b II B	II.	26. März 78	„	♀	IV—V	55	„ „
207.5			a II	2 b II C	b II. β	16. Mai 78	„	♂	VII	55	„ „
				2 b II B	b III. β	4. Mai 78	„	♀	VII		„ „
• .6				2 c II B	b III. β	„	„	♀	III—IV	55	mässig fett
.7	c	1	2 a I	2 b II B	a II. α	17. August 78	Kiel	♂	I—II	57	auss. fett
208.0				2 b II B	b II. β	4. Mai 78	Schlei	♂	VI		wenig Fett
	c		2	3 b		10. März 76	Kiel	♂	IV		„ „
.5			a II	2 b II A	b II. β	16. Mai 78	Schlei	♂	VII	56	ohne Fett
209.0				2 b II B	b III. γ	4. Mai 78	„	♂	V	55	wenig Fett
	c	1	3 a I	2 c II B	II.	5. Juli 78	Kiel	♀	VII—II		auss. fett
• .2	b	1	2 b II	2 b II B		15. Juli 78	„	♂	III—IV		sehr fett
.5				2 b II B	b II. β	4. Mai 78	Schlei	♂	III—IV	54	mässig fett
210.0	c		2	2 b		3. März 76	Kiel	♀	IV		wenig Fett
•			a I	2 b II B	c II. γ	16. Mai 78	Schlei	♂	VI	55	„ „
	c	1	2 a II	2 c III C	a II. β	29. Nov. 77	Kiel	♀	II		sehr fett
	b	1	3 a I	3 b II B	b III. γ	14. August 78	„	♀	II	55	„ „
				3 b II		15. März 78	„	♂	III—IV		recht fett
.5	c	1	3 a I	2 b II B	b II. β	17. August 78	„		II		auss. fett
211.0	c	1	3	3 b II B	II.	23. Mai 77	Schlei	♂	II ? VII		

var. a

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
*211.5	b	1	1 c II	1 a II A	b III. β	15. Juli 78	Kiel	♂	II		sehr fett
.6				2 b I B		15. März 78	„	♂	II		mässig fett
*212.0			a II	2 a II B	b III. γ	16. Mai 78	Schlei	♀	VII	56	wenig Fett
				1 b II B	c III. δ	4. Mai 78	„	♂	V		wg. K.12+25.V.7|8
				1 a I		16. März 78	Kiel	♀	II		sehr fett
213.0	c	1	3 b I	2 a II B	b II. β	29. Nov. 77	Kiel	♀	II		auss. fett
*				1 a I B	a II. β	4. Mai 78	Schlei	♀	V	56	wenig Fett
214.0	b	2	3 b I	1 b II B	b II. β	9. Nov. 77	Kiel	♂	IV--V	56	wenig Fett
				2 a II B		15. März 78	„	♀	II		viel Fett ㉛
*215.0			a I	1 a II A	b II. β	16. Mai 78	Schlei	♂	VII	55	wenig Fett
216.5				1 a I A	II.	15. März 78	Kiel	♂	II		recht fett
*217.5				1 b II B	b II. β	4. Mai 78	Schlei	♀	VII	55	wenig Fett
218.2				3 a I B		15. März 78	Kiel	♂	II		sehr fett
219.0				2 a I B	II.	15. März 78	„	♀	II		sehr fett
220.0				2 a I A	II.	15. März 78	„	♀	II		sehr fett
	c		3	2 a		17. Nov. 75	„	♀	II		sehr fett
*220.5	c	1	2 a I	2 a II B	a II. α	8. Nov. 77	„	♀	II	56	ziemlich fett
221.0			a I			15. März 78	„	♂	IV		wenig Fett
*			2 b I	1 a I B	b II. β	11. Nov. 77	„	♂	V		wenig Fett
	b	1	2 b I	1 b II B	II.	15. Juli 78	„		II		auss. fett
	c		2	2 a		10. März 76	„	♀	II		sehr fett
*222.0	b		2	2 a		3. März 76	„	♀	IV		mässig fett

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
211.3	c	1	3 a II	2 b II B	b II. β	9. Juli 78	Kiel	♀	II		auss. fett
.5			a I	3 b II B	a III. β	16. Mai 78	Schlei	♂	VII	56	wenig Fett
.5				3 c II		18. März 78	„	♂	IV		ohne Fett
212.0	c	1	3 a I	3 b III B	a II. α	29. Nov. 77	Kiel	♀	II—III		auss. fett
	c	2		3 c		3. März 76	„	♂	IV		ohne Fett
.5	c	2		2 b		„	„	♀	IV		wenig Fett
.5				2 b II B		15. März 78	„	♂	IV		mässig fett
.8	c	1	2 b II	3 b II B	b II. β	14. Aug. 78	„	♀	II	55	auss. fett
213.0				3 c II B	b II. β	4. Mai 78	Schlei	♂	IV		mässig fett
.6			a I	2 b III B	c II. γ	16. Mai 78	„	♀	VII	56	ohne Fett
*214.0	c		3	3 c		6. März 76	Kiel	♀	III—IV		mässig fett
	c	1	2 b II	2 b II C	a I. α	21. Nov. 77	„	♀	IV—V		ziemlich fett
	c	1	2 a II	3 b III B	b III. β	15. Juli 78	„	♂	II		auss. fett
	c	1	2 a I	2 b II B	II.	Winter 74	„	♂			
				2 b II		18. März 78	Schlei	♀	III—IV		sehr fett
			a I	2 b II B	b III. γ	16. Mai 78	„	♀	VII	55	ohne Fett
215.0			b II	2 b II B	b III. γ	„	„	♀	VII	56	„ „
	c		2	3 b		17. Nov. 75	Kiel	♀	IV		ziemlich fett
.0	c		3	3 b		27. Januar 76	„	♀	IV		mässig fett
.5				2 c II B	b II. β	4. Mai 78	Schlei	♀	V—VI		ohne Fett
.5			b I	2 b III C	c III. γ	16. Mai 78	„	♂	VII	53	wenig Fett
216.0	c	1	3 a I	3 b II B	b III. γ	14. Aug. 78	Kiel	♀	II	55	auss. fett
			a II	2 b II B	b II. β	16. Mai 78	Schlei	♂	VII	56	wenig Fett
	c		2	3 b		3. März 76	Kiel	♀	III—IV		ziemlich fett
.6	b	1	2 b II	2 c III B	c III. γ	17. Aug. 78	„	♀	II	55	auss. fett
217.0	c		3	3 d		6. März 76	„	♀	III		ziemlich fett
				2 b II B	b II. β	4. Mai 78	Schlei	♂	IV—V	55	mässig fett
			a I	2 b II B	b III. γ	16. Mai 78	„	♀	VII	55	ohne Fett
	c		3	2 b		29. October 75	Kiel	♀	II		sehr fett
.5	c	1	2 a I	2 b II A	b II. β	3. Juli 78	„	♀	II		„ „
			a I	2 b II B	c II. β	16. Mai 78	Schlei	♂	VI—VII	55	ohne Fett
218.0				3 b II C	b III. β	4. Mai 78	„	♀	V	57	mässig fett
	c	1	3	3 d II B	II.	23. Mai 77	„	♀	V		
	c		2	3 b		29. October 75	Kiel	♂	II		sehr fett
.5			a I	2 c II C	b II. β	16. Mai 78	Schlei	♂	VI—VII	56	wenig Fett
*219.0	c		2	2 b		17. Nov. 75	Kiel	♀	II		sehr fett
				2 c II B	b III. γ	4. Mai 78	Schlei	♂	V—VI		wenig Fett
				2 b II B	b III. γ	„	„	♀	IV—V	55	„ „
				2 b II		26. März 78	„	♂	IV—V	56	„ „
	c	1	2 a II	3 b II C	b II. β	3. Juli 78.	Kiel	♀	II		auss. fett
.5	c	1	3 a I	2 b II B	b II. β	29. Nov. 77	„	♂	II—III		„ „
220.0				2 b II B	a III. β	26. März 78	Schlei	♀	IV	55	mässig fett
				3 b I C		15. März 78	Kiel	♀	V		sehr wenig Fett
.0	c	1	2 b II	3 b II B	b III. γ	15. Juli 78	„	♀	VII		auss. fett
.5				3 c II B	b II. β	4. Mai 78	Schlei	♀	VI	56	wenig Fett
*221.0	c		3	2 b		10. März 76	Kiel	♂	II		ziemlich fett
				2 b II		18. März 78	„	♂	IV—V		ohne Fett
				3 b II B		„	„	♂	IV		„ „
	c	1		3 b II B	b II. β	5. Juli 78	„	♂	II		auss. fett
.3				2 b II B		18. März 78	„	♂	IV		wenig Fett
* .5				2 b II		15. März 78	„	♀	II		ohne Fett
222.0				2 b II		18. März 78	„	♂	IV		„ „
	b	1		2 b II B	II.	October 76	Eckernförde				
.5				2 b II B	c II. γ	4. Mai 78	Schlei	♂	VII	56	wenig Fett
.5				2 b II B	a II. β	26. März 78	„	♂	IV—V	55	ohne Fett
223.0	c		3	3 c		6. März 76	Kiel	♀	III		recht fett
	c	1	3 a II	2 b II B	b II. β	9. Nov. 77	„	♂	IV	56	wenig Fett
*				2 b II C		15. März 78	„	♀	II		mässig fett
				2 c II		18. März 78	Schlei	♂	IV		wenig Fett

var. a

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
224.0				2 a I B	II.	15. März 78	Kiel	♀	II		recht fett
*225.0	b		3	2 a		10. März 76	„	♀	II		ziemlich fett
225.0				2 a II C	II.	15. März 78	„	♂	IV		wenig Fett
226.5				2 b I B	b III. γ	4. Mai 78	Schlei	♂	IV		wenig Fett
				2 b I B		15. März 78	Kiel	♂	II		sehr fett
*				1 b II B	II.	26. März 78	Schlei	♀	II	55	ohne Fett
*227.0	c	1	2	2 a I A	II.	23. Mai 77	„	♀	VII		
*	c	1	3 a I	1 b II B	a II. α	9. Nov. 77	Kiel	♀	III		recht fett
·5	b	1	3 a I	1 b II A	b I. α	29. Nov. 77	„	♂	II		mässig fett
·7				2 a I B	I.	15. März 78	„	♂	II		recht fett
228.0	b	1	3 a I	2 a II B	a II. β	8. Nov. 77	„	♀	II	55	„ „
* ·5	c	1	2	2 b I B	II.	23. Mai 77	Schlei	♂	V—VI		
				2 a I B		15. März 78	Kiel	♂	II		ohne Fett
				1 a I B		„	„	♀	II		sehr fett
229.0	b	1	4 a I	2 a II B	a II. β	11. Nov. 77	„	♂	VII		wenig Fett
	c	1	2 b II	2 a II B	II.	October 76	Eckernförde				
	b	1	2 a I	2 a II B	a II. β	21. Nov. 77	Kiel	♀	IV		ziemlich fett
*229.5			a I	2 a I A	b III. β	16. Mai 78	Schlei	♀	VII	55	ohne Fett
230.0				2 a I B	a o. o	15. März 78	Kiel	♂	II		mässig fett
	c	1	3 a I	2 a I A	a II. α	5. Nov. 77	„			56	
	c		1	1 b		17. Nov. 75	„	♂	IV		recht fett
*	c		2	2 a		27. Januar 76	„	♂	IV—V		ohne Fett
·5				2 a II C		15. März 78	„	♂	II		ziemlich fett
*231.0				1 a I B		16. März 78	„	♀	VI		ohne Fett
		1	2 a II	2 a o A	a I. α	9. Nov. 78	„	♀	V	56	„ „
·5			3 a I	2 a II B	III.	16. März 78	„	♀	II		recht fett
*232.0	b	1	2 a II	2 o II B	a III. β	9. Nov. 77	„	♂	IV	55	ziemlich fett
	c	1	4 o I	2 a II A	b II. β	„	„	♀	VII	55	wenig Fett
.6				2 a I A	II.	15. März 78	„	♂	II		recht fett
233.0	c	1	3 a I	1 b II B	a I. α	29. Nov. 77	„	♀	II		ziemlich fett
*	b	2	2	2 a II B	II.	23. Mai 77	Schlei	♀	V		
	b		3	2 a		6. März 76	Kiel	♂	II		„ „
*234.0	c		2	1 b		27 October 75	Kiel	♂	IV—V		recht fett
234.0	c	1	3 a I	2 a II B	b II. β	13. Nov. 77	„	♀	II		ziemlich fett
	c	1	3 a I	2 a II B	b III. β	6. Nov. 77	„				
235.0	b	1	4 a I	1 a I B	o II. α	9. Nov. 77	„	♂	II		wenig Fett

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen.				Datum.	Ort.	Geschlecht und Reife		Vert.	Bemerkungen
223.0				2 b II C	III.	26. März 78	Schlei	♀	IV	55	ohne Fett
				2 b II B	b II. β	4. Mai 78	„	♂	IV	54	wenig Fett
224.0	c	1	3	2 b II B	II.	23. Mai 77	„	♀	VII		
			2 a II	2 b II B	b II. β	26. März 78	„	♂	IV	56	„
• .5	c	1	2 a I	2 b III	a	21. Nov. 77	Kiel	♀	IV—V		$K_1 = 7$
5				3 b II B	III.	18. März 78	Schlei	♀	IV		ohne Fett
				2 b II B	b III. γ	4. Mai 78	„	♀	VI	56	„ „
•225.0		1	2 a II	2 b II B	a II. α	11. Nov. 77	Kiel	♂	IV—V		ziemlich fett
225.0	c	1	2 b II	2 c II B	III.	5. Juli 78	„	♀	I—II		auss. fett
.5				3 b I B		18. März 78	Schlei	♂	IV		ohne Fett
.5			b I	2 b II B	a II. β	26. März 78	„	♀	V	54	wenig Fett
226.0			3 a II	2 c II B	II.	„	„	♂	IV	55	wenig Fett
•	c	1	3 a I	2 b II B		29. Nov. 77	Kiel	♀	II		ziemlich fett
	c	1	2 b II	3 b III C	II.	15. Juli 78	„		VII		auss. fett
	c	1	2 a I	2 b II C							
.6	c	1	2 a II	2 b I B	a I. α	„	„	♀	VII		„ „
.8	b	1	2 b I	2 b II B		20. Aug. 78	„		II		sehr fett
227.0				2 b II C	II.	15. Juli 78	„	♂	II		auss. fett
	c	1	1	2 b II B	III.	23 Mai 77	Schlei	♀	V		
•	c	1	2 a I	2 b II B	b II. β	8. Nov. 77	Kiel	♂	VI		
.5	c	1	2 a I	3 c II B	II.	5. Juli 78	„	♀	II		„ „ Ventr. 9|7
	c	1	3	3 b		27. Januar 76	„	♂	III		mässig fett
228.0				2 b II B	b II. β	4. Mai 78	Schlei	♂	V	56	wenig Fett
• .5				2 b II		9. Nov. 77	Kiel	♂	IV—V	58	
.5				2 b II B	III.	18. März 78	Schlei	♂	IV		wenig Fett
				2 b II B	b III. β	4. Mai 78	„	♀	VI—VII	55	ohne Fett
•	c	1	3 a I	2 b II B	b II. β	21. Nov. 77	Kiel	♀	VII—II		wenig Fett
229.0				2 a III B	III.	18. März 78	Schlei	♂	IV		„
				2 b I B	b II. β	4. Mai 78	„	♀	V		mässig fett
			a I	2 b II B	b III. γ	16. Mai 78	„	♀	VI	56	wenig Fett
230.0				2 c II B	II.	18. März 78	„	♀	IV—V		ohne Fett
	c		2	3 b		1. Dec. 75	Kiel	♀	III		sehr fett
	c		2	2 b		24. Nov. 75	„	♀	III		
				2 b II B	III.	18. März 78	Schlei	♀	V		ohne Fett
	c	1	3 a I	3 b II A	II.	Winter 74	Kiel	♀			
.5				2 c II		18. März 78	Schlei	♀	V		wenig Fett
				3 b II C	b III. γ	4. Mai 78	„	♀	VII		„ „
231.0				2 c II		18. März 78	„	♂	IV—V		„ „
.2			2 a II	2 b II B	b II. β	26. März 78	„	♂	IV—V	54	„ „
.5				2 b II C	II.	15. März 78	Kiel	♂	II		sehr fett
				2 b II B	b II. β	4. Mai 78	Schlei	♀	V—VI	56	recht fett
	c	1	2 a II	2 b II B	a I. α	16. Nov. 77	Kiel	♀	IV		„ „
232.0	c	1	3	3 b II B	II.	23. Mai 77	Schlei	♂	VI		
•	c	1	2	3 d II A	II.	„	„	♀	V		
	c		2	3 c		3. Nov. 75	Kiel	♂	IV		„ „
	c		2	2 b		27. Januar 76	„	♀	IV		mässig fett
	c		2	3 b		3. März 76	„	♀	IV—V		ohne Fett
233.0	c		2	2 b		„	„	♀	III—IV		wenig Fett
.5	c	1	3 a I	2 b II C	b II. β	29. Nov. 77	„	♀	III		sehr fett
234.0			2 a I	2 b II B	b III. β	26. März 78	Schlei	♂	IV	55	wenig Fett
•234.5		1	2 a I	2 b II B	b II. β	21. Nov. 77	Kiel	♀	IV—V		„ „
•	c	1	2 a II	2 b II A	a III. β	11. Nov. 77	„	♀	V—VI		recht fett
235.0	b	1	3	2 b II B	II.	23. Mai 77	Schlei	♀	VII		

var. a

e	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
	b	1	3 a I	1 a I B	b II. β	11. Novbr. 77	Kiel	♂	II		mässig fett
	b	1	3 a I	2 a I B	b II. β	29. Novbr. 77	„	♀	VII—II		ziemlich fett
				2 a I B	II.	15. März 78	„	♂	II		„ „
			a I	2 a II B	a III. β	16. Mai 78	Schlei	♂	II	56	ohne Fett
				2 a II C	III.	18. März 78	„	♀	IV—V		„ „
			a I	2 a II A	II.	26. März 78	„	♀	VI	57	„ „
	c	1	2	2 a I A	II.	23. Mai 77	„	♀	V		
	c	1	3 a	1 b II B	a III. β	29. Novbr. 77	Kiel	♂	II		sehr fett
	c		2	2 a		3. Novbr. 75	„	♂	IV		„ „
	c	1	1 b II	1 b II B	b II. β	10. August 78	„	♀	II	55	„ „
	c	1	3	2 a II B	III.	23. Mai 77	Schlei	♀	VII		
	c	1	3 a I	2 a II B	a II. α	8. Novbr. 77	Kiel	♂	II	56	„ „
				2 a I B		15. März 78	„	♀	II		wenig Fett
	c	1	2 b I	2 a II B	II.	October 76	Eckernförde				
	c		1	3 a		8. März 76	Kiel	♀	V—VI		ohne Fett
	c	1	2 a I	2 b I A	a II. α	5. Novbr. 77	„			57	
	c	1	3 o I	2 a I B	a II. α	16. Novbr. 77	„	♂	II		sehr fett
	c	1	3	2 a I B	III.	23. Mai 77	Schlei	♀	VII		
	c		3	3 a		27. Januar 76	Kiel	♀	II		wenig Fett
	b	1	b I	2 a II B	III.	Winter 74	„	♀			
	c	1	3 a I	2 a I B	a II. α	16. Novbr. 77	„	♀	VII		ohne Fett
	c	1	3 o I	1 a I B	a II. α	11. Novbr. 77	„	♀	VII—II		wenig Fett
	b	1	3 a I	2 o II B	a III. β	5. Novbr. 77	„			56	
	c	1	2 b I	1 a I A	a II. α	5. Juli 78	„	♂	II		ausserordentl. fett
	b	1	3 a I	1 a I B	II.	13. Novbr. 77	„	♀	VII—II		wenig Fett
	c	1	2 a I	2 a I A	II.	Winter 74	„	♂			
	c	1	2 b II	1 b I B	I.	October 76	Eckernförde				
	c		2	3 a		3. März 76	Kiel	♀	V		ohne Fett
	b	1	2 b I	2 a II C	b III. γ	17. August 78	„	♀	II	56	ausserordentl. fett
	c	1	3 a I	2 a I B	b II. β	16. Novbr. 77	„	♀	II		sehr fett
	c	1	3 a I	1 b I B	a II. α	5. Novbr. 77	„			56	
	c	1	a I	2 a I B	b II. β	13. Novbr. 77	„	♀	VII—II		wenig Fett
	c	1	2 a I	2 a II A	II.	Winter 74	„				
	b	1	2 a I	1 a II B	b II. β	13. Novbr. 77	„	♀	V		" "
	c	1	3 a I	2 a II B	b II. β	6. Novbr. 77	„				

var. b

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkunger
235.0	c	1	3 a l	2 b II B	o II. α	5. Juli 78	Kiel	♀	II		auss. fett
*	c	1	2 a l	2 b II A	a II. α	11. Nov. 77	„	♂	IV—V		mässig fett
.5				2 b II A	b II. β	4. Mai 78	Schlei	♀	VII—II		wenig Fett
*236.0	c		1	2 b		1. Dec. 75	Kiel	♂	IV—V		wenig Fett
.2				2 b I B	II.	18. März 78	Schlei	♂	IV		ohne Fett
.3				2 b II C		„	„	♂	IV		wenig Fett
.5	c	1	2 a II	2 b II B	a II. α	29. Nov. 77	Kiel	♀	III		„ „
	c	1	2 b l	2 c II C	b I. α	9. Nov. 77	„	♂	IV	56	„ „
237.0	c	1	2 a l	2 b II B	b II. β	5. Juli 78	„	♀	II		recht fett
	c	1	1 b II	3 b II B	III.	Winter 74	„	♀			
*		1	2 a II	2 b II B	a II. β	11. Nov. 77	„	♀	II		„ „
	c		1	2 b		1. Dec. 75	„	♂	IV—V		mässig fett
*238.0				2 b II B	II.	18. März 78	Schlei	♂	II		ohne Fett
				2 c II B	b II. β	15. Juli 78	Kiel	♀	II		sehr fett
	c		1	2 b		24. Nov. 75	„	♀	IV		mässig fett
	c		3	2 b		3. März 76	„	♂	IV—V		ohne Fett
.5				2 b II B	II.	18. März 78	Schlei	♂	IV—V		„ „
239.0	c	1	3 a l	2 b II C	II.	29. Nov. 77	Kiel	♂	II		recht fett
	c	1	3 a l	2 b III B	b III. γ	16. Nov. 77	„	♂	III		sehr fett
	c	1	2	3 b II B	II.	23. Mai 77	Schlei	♂	VI		
	c		2	3 b		4. Februar 76	Kiel	♂	IV—V		
.5			2 o l	2 b II C	b III. β	26. März 78	Schlei	♂	IV—V	55	wenig Fett
*240.0	c		2	3 b		29. Oct. 75	Kiel	♂	IV		mässig fett
	c		2	3 b		4. Februar 76	„	♂	V		wenig Fett
.5				2 b II B		26. März 78	Schlei	♀	IV—V	56	„ „
241.0	c	1	2 b l	2 b II C	b II. β	6. Nov. 77	Kiel				
	c	1	2 a l	3 b II B	II.	Winter 74	„	♀			
*	b	1	3 a l	2 b II B	b II. β	16. Nov. 77	„	♀	VII		„ „
	c		2	2 b		27. Januar 76	„	♂	V		„ „
	c		2	2 b		„	„	♂	V		„ „
242.0	c	1	2 b l	2 b II B	b II. β	15. Juli 78	„	♀	VII—II		auss. fett
	c	1	2 a II	2 b II B	a II. β	16. Nov. 77	„	♀	III		recht fett
	c	1	2 a l	3 a II B	a II. α	10. August 78	„	♂	II	56	sehr fett
*	c		2	2 b		27. Oct. 75	„	♂	IV—V		„ „
243.0	c	1	2	2 b II B	II.	23. Mai 77	Schlei	♂	VI		
	c		2	3 c		4. Februar 76	Kiel	♀	IV		wenig Fett
	c		2	2 b		3. März 76	„	♀	V		ohne Fett
244.0	c	1	3 a l	2 b II C	b II. β	29. Nov. 77	„	♀	II—III		auss. fett
	c	1	3 a l	2 b II A	b II. β	5. Juli 78	„	♂	II		„ „
245.0	c	1	3 a l	2 b II B	a II. β	16. Nov. 77	„	♂	II		recht fett
*246.0	c	1	3 a l	2 b II B	a II. β	29. Nov. 77	„	♀	VII		ziemlich fett
	c	1	2 b II	3 b II B	b II. β	15. Juli 78	„	♀	II		auss. fett
*247.0				2 b II	II.	26. März 78	Schlei	♂	VII	56	ohne Fett
	b	1	2 a l	3 b II C	b III. β	13. Nov. 77	Kiel	♂	II		sehr fett
248.0	c		1	3 b		8. März 76	„	♀	V—VI		ohne Fett
	c	1	1 b l	2 b II B	a I. α	5. Nov. 77	„			57	
	c		2	2 b		3. Nov. 75	„	♀	III		sehr fett
	c		2	3 b		27. Januar 76	„	♂	IV		wenig Fett
	c		2	3 b		„	„	♀	V		„ „
	c		1	2 b		3. März 76	„	♀	V		ohne Fett
	c		2	2 b		„	„	♀	V		„ „
*249.0	c	1	2 a l	2 b II B	a II. β	9. Nov. 78	„	♀	IV—V	6	„ „
	c	1	3	2 b II B	II.	23. Mai 77	Schlei	♀	VII		
	c	1	2	3 b II B	III.	„	„	♀	V		
250.0	c	1	2 a l	2 b II B	III.	Winter 74	Kiel	♀			
251.0	c	1	2 a l	2 b II B	b II. β	5. Juli 78	„	♀	VII—II		auss. fett
	c	1	2	2 b I B	II.	23. Mai 77	Schlei	♀	V		

var. a

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
*253.0				2 a ll B	ll.	15. März 78	Kiel	♂	VI		mässig fett
*254.0				1 b ll B		18. März 78	Schlei	♀	V		ohne Fett
	c	1	3 o l	1 b l B	o ll. o	5. Novbr. 77	Kiel	♀	IV	56	ziemlich fett
258.0	c	1	b l	2 a l B	ll.	Mai 77	Eckernförde				
	c	1	2 b l	2 a l B	b ll. β	6. Decbr. 77	Kiel	♂	V	56	ohne Fett
259.0	c	1	1 b l	1 a l C	lll.	Septbr. 76	Eckernförde				
262.0	c	1	2 a ll	2 b l B	a ll. α	16. Novbr. 77	Kiel	♂	II		sehr fett
267.0	b	1	3 b l	2 a ll A	ll.	Mai 77	Eckernförde				
*270.0	b	1	1 b l	2 a l A	b ll. β	3. Decbr. 77	Kiel	♀	IV		ausserordentl. fett
*	b	1	2 b l	2 a l A	b ll. β	"	"	♂	IV		wenig Fett
*271.0	c	1	3 a l	2 b l B	b ll. β	6. Decbr. 77	"	♀	III—IV	55	recht fett
	b	1	2 b l	2 a ll B	ll.	März 77	Eckernförde				
272.0	b	1	2 b l	1 a l B	b lll. β	15. Juli 78	Kiel	♀	II—III		sehr fett
273.0	b	1	2 b l	1 a l B	lll.	Mai 76	Eckernförde				
274.0	c	1	3 a l	2 o l B	a lll. β	6. Novbr. 77	Kiel				
*	b	1	2 b l	2 a l A	b lll. γ	9. Juli 78	"	♂	II		ausserordentl. fett
276.0	b	1	1 b l	2 a o B	ll.	Octbr. 76	Eckernförde				
	c	1	3 a l	2 a ll B	a ll. β	6. Decbr. 77	Kiel	♀	VII	56	ziemlich fett
278.0	c	1	1 b l	2 b l A	b l. β	28. Novbr. 77	"	♀	V		ohne Fett
279.0	b	1	1 b l	1 a l B	ll.	27. Octbr. 75	Eckernförde				
*281.0	c	1	1 b ll	1 b l B	a ll. β	18. März 78	Kiel	♂	V		wenig Fett
285.0	c	1	1 b l	1 b l B	b ll. β	28. Novbr. 77	"	♀	V		ohne Fett
291.0	b	1	3 b l	2 a l B	ll.	Decbr. 75	Eckernförde				
*294.0	b	1	1 b ll	1 a ll B	b ll. β	25. Jan. 78	Kiel	♀	V		" "
295.0	b	1	2 a l	2 a ll B	b lll. β	21. Febr. 78	"		steril	55	ausserordentl. fett
296.0	c	1	3 a l	1 a l B	b ll. β	7. Novbr. 77	"	♀	VII		wenig Fett
*297.0	c	1	2 a l	2 a o B	a ll. β	22. Jan. 78	"	♀	IV		mässig fett
311.0	c	1	3 a l	2 b l B	a ll. α	25. Jan. 78	"	♂	steril		wenig Fett
316.0	c	1	3 a l	2 a ll C	b lll. β	21. Febr. 78	"	♀	VII		

var. b

Totallänge mm	Seitliche Kopflänge	Formel der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Vert.	Bemerkungen
253.0	c	1	3 a 1	2 b II B	b II. β	29. Nov. 77	Kiel	♂	II.		recht fett
				2 b II B	III.	16. März 78	„	♀	VI		ohne Fett
256.0	c	2	2	3 b II C	II.	23. Mai 77	Schlei	♂	VII		
257.0	b	1	2 b 1	2 b II B	b III. γ	10. August 78	Kiel	♀	II	55	auss. fett
259.0	c	1	a 1	3 b II B	II.	Nov. 75	„	♂			
260.0	c		3	3 c		6. Nov. 75.	„	♀	III		recht fett
262.0	c	1	2 a 1	3 b II B	II.	Winter 74.	„	♂			
271.0	c	1	2	2 b II B	II.	23. Mai 77	Schlei	♂	V		
286.0	c	1	2 b 1	2 b II B	b II. β	23. März 78	Kiel	♂	V		wenig Fett
*287.0	c		1	2 b		21. Dec. 75	„	♂	V		ohne Fett
291.5	c	1	2 a 1	3 b II A	I.	19. Dec. 77	„	♀	IV	56	ziemlich fett
310.0	b	2	3 a 1	2 b II C	a II. α	18. März 78	Kiel	♀	VI		ohne Fett

Table XIX. Comparison of very similar herring and sprat

Any two fish listed at the same place in each part of the table are most similar to each other; e.g., herring 86.2 and sprat 128.0.

Key: 1- total length 2- lateral head length 3- formulae of height and length measurements and keel scales 4- date 5- place 6- sex and maturation stage 7- remarks 8- May 9- spring 10- March 11- June 12- January 13- keel scales

Hering. *Clupea harengus.* Herring.

Totallänge. mm ①	Seitliche Kopflänge ②	Forme ③ der Höhen, Längen und Kielschuppen				Datum ④	Ort ⑤	Geschlecht und Reife ⑥		Bemerkungen ⑦
*212.0				1 b II B	c III. δ	4. Mai ⑧ 78	Schlei	♂	V	12+25 Kielsch. ⑬ V. 8|7
327.0	b	2	2	1 b II C	II.	Frühjahr ⑨ 76	Bergen		VII	
234.0	b	1	2	1 b II C	II.		Canal			
209.0				1 b II C	b III. β	4. Mai 78	Schlei	♀	VI	
58.5	a	2	2 c II	1 b II C	a II. β	26. Aug. 75	Kiel			
155.0	b	1	2 b II	1 b III C	b II. β	Nov. 77	Elbe		I	
57.5	a	1	o o	1 b III C			Island			
79.0	b	1	3 b I	1 c II A	II.	26. Nov. 74	Schlei			
157.7	b	1	1 c II	1 c II B	a I. α	Nov. 77	Elbe		I	
86.2	b	1	2 c II	1 c III B		17. Aug. 78	Kiel			
64.1	b	1	3 b II	1 c III B	b III. γ	17. Sept. 77	Schlei			
219.0	c	1	3 a I	2 c III C	II.	⑩ März 73	Greifswald			
215.0	c	2	2 b I	2 c III C	II.	1. Juni 75 ⑪	Dassow		VII	
172.0	a	2	3 a II	2 c III C	b II. β	23. März 78	Kiel			
85.0				2 c III C		6. März 75	Eckernförde			
* 83.4	b	2	2 b II	2 c III C	III.	24. Sept. 74	Schlei			
71.2	b	1	2 c II	2 c III C		9. Aug. 78	Kiel			
62.7	b	1	2 c III	2 c III C	c II. γ	9. Aug. 74	Schlei			
72.0	a	1	2 c II	2 c IV C	b III. γ	17. Aug. 78	Kiel			
173.7	b	1	2 b II	2 b IV B	a II. α	Nov. 77	Elbe		I	
**79.0	b	1	2 b II	3 c IV B	d III. δ	März 76	Kiel			12+24 Kielsch. V. 8
235.5	b	1	2 b II	1 b II A	a IV. γ	Januar ⑫ 77	Gothenburg	♀	VII—II	11+29 Kielsch.

Sprott. *Clupea sprattus.* Sprat.

Totallänge. mm	Seitliche Kopflänge	Forme der Höhen, Längen und Kielschuppen				Datum	Ort	Geschlecht und Reife		Bemerkungen
*131.0	c	2	1 b II	1 b II C	d III. δ	December 75	Eckernförde			23+12=35 Kielsch.
*137.0	c	1	1 c II	1 b III C	III.	Juni 75	Kiel			
136.0	c	2	2 b II	1 b III C	e IV. ε	October 76	Eckernförde			
*135.0	c	1	2 b II	1 b III C	d IV. ε	März 77	„			
135.0	c	1	1 b II	1 b III C	IV.	Juni 75	Kiel			
*136.0	c	1	1 b II	1 c III C	d III. δ	December 75	Eckernförde			23+12=35 Kielsch.
*136.0	c	1	2 b II	1 c III C	e IV. ε	Mai 77	„			
146.5				1 c II C	e III. ε	April 78	Kiel			
*135.0	c	2	2 b II	1 c III C	III.	October 72	„			
*128.0	c	2	2 b II	1 c III C	III.	Juni 75	„			
*112.6	c	2	2 a I	1 c III C	e III. ε	Mai 77	Eckernförde			
138.7				1 c III C	e III. ε	April 78	Kiel			
117.5	c	2	2 a II	1 c III D	d III. δ	Mai 77	Eckernförde			23+12=35 Kielsch.
*137.8	c	2	2 a II	2 c III C	d III. δ	März 77	„			23+12=35 Kielsch.
132.2	c	1	1 b	2 c III C	e III. ε	November 77	Elbe			
*118.3	c	1	2 b II	2 c III C	d IV. δ	Mai 77	Eckernförde			
84.0	b	2	3 a II	2 b III D	d IV. ε	„	„			
63.0	b	2	3 b III	2 b III E	e III. ε	16. Sept. 75	„			

Figures.

Fig. 1. Outline drawing of a sexually mature Var. A herring (reduced scale). Formula: b-1-2bI-1aIB.

Fig. 2. Outline drawing (reduced scale) of a sexually mature Var. B herring. Formula: c-1-3aI-2bIIIB.

Fig. 3. Outline drawing of a sexually mature Var. C herring. Formula: b-2-3bI-1aIIIC.

Fig. 4. Outline drawing of a Var. A larva with total length 30 mm from Kiel Harbor (magnification 2x). Formula: f-1-(8-f-II)-(-2e-II0).

Fig. 5. Outline drawing of a Var. B larva 30.5 mm long from the Schlei (magnification 2x). Formula: e-1-(7-d-I)-(0d-I0).

Fig. 6. Outline drawing of a Var. A larva 41.5 mm long from Kiel Harbor (magnification 2x). Formula: d-1-(6-d0)-(-1b00).

Fig. 7. Outline drawing of a Var. B herring in the transitional stage 41.5 mm long from the Schlei (magnification 2x). Formula: a-1-3aII-1cIIIB.

Fig. 8. Outline drawing of a Var. A herring in the transitional stage 55.7 mm long from Kiel Harbor (magnification 2x). Formula: a-1-30I-1aIA.

Fig. 9. Outline drawing of a young herring of Var. B with 127 mm total length. Formula: b-1-2bII-3bIIB.

Fig. 10. Outline drawing of a young herring from the Lower Elbe, reduced to 127 mm total length. Formula: b-1-1cIII-2aIIB.

Fig. 11. Outline drawing of a sexually mature sprat from Kiel Harbor, reduced to 127 mm total length. Formula: c-2-1bII-2cIIIE.

Fig. 12. Outline drawing of an adult sprat from the Lower Elbe, reduced to 127 mm total length. Formula: c-2-(-1dIV)-2dIVE.

Fig. 13. A young herring and (Fig. 14) a sprat from Kiel Harbor with the same formulae for height measurements and fin locations. Common formula: 2- 2bII-1bIIIC.

Note: In all drawings of herring, with the exception of larvae and transitional stages, only those differences expressed in the formulae are shown; other parts are the same in all figures.

Var. A.

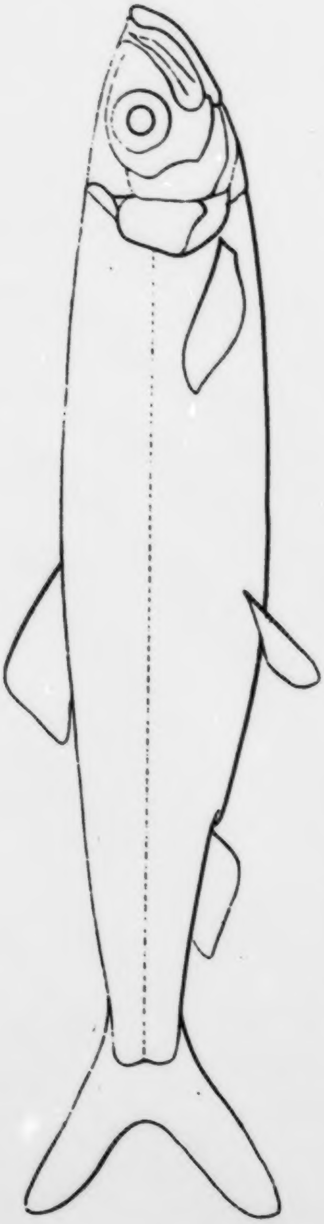


Fig. 1.

Var. B.

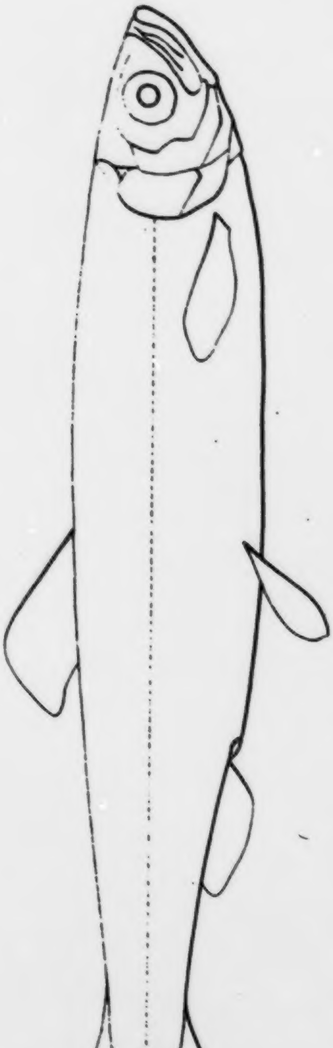


Fig. 2.

Var. C.

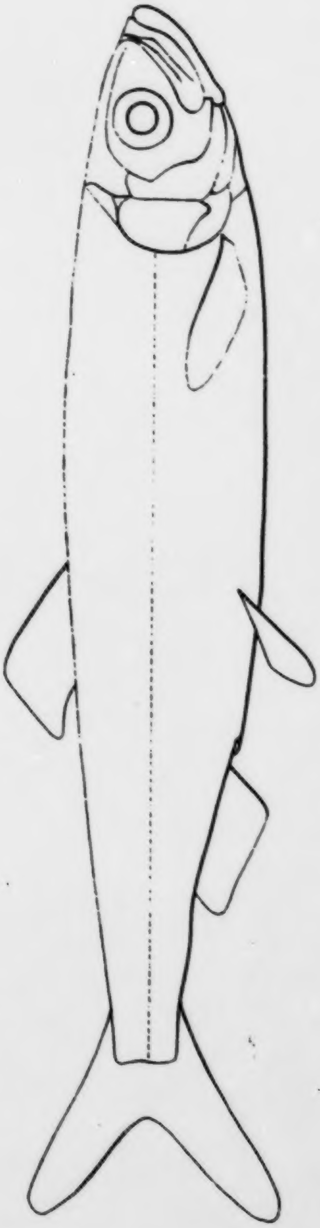
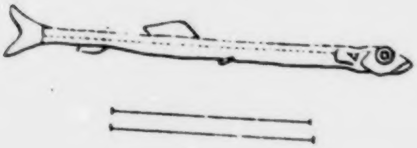


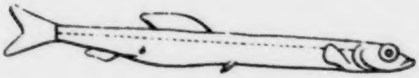
Fig. 3.

Fig. 4.



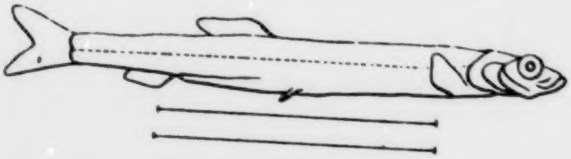
Var. A.

Fig. 5.



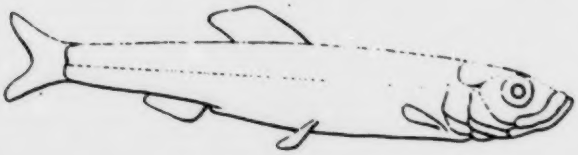
Var. B.

Fig. 6.



Var. A.

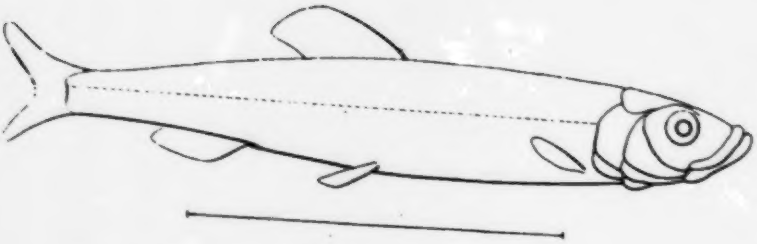
Fig. 7.



Var. B.

2

Fig. 8.



Var. A.

Fig. 9.

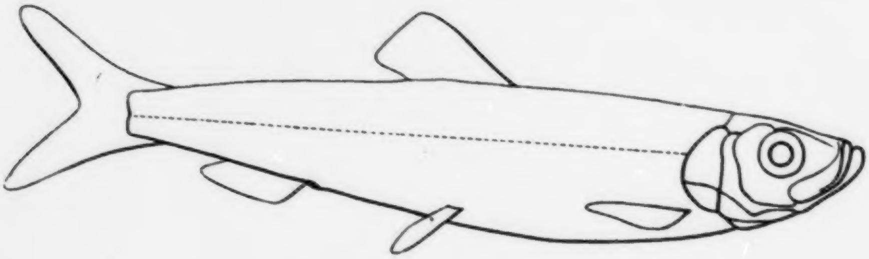


Fig. 10.

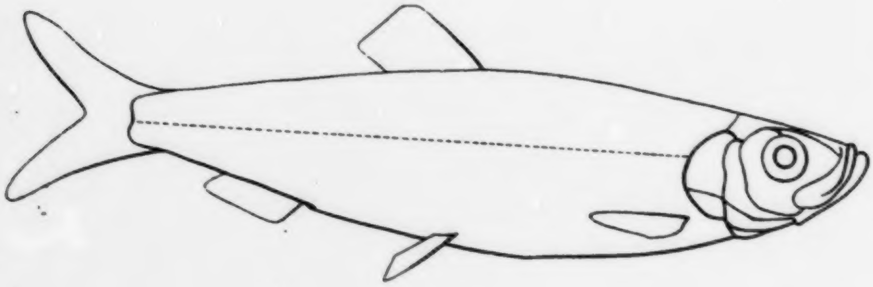


Fig. 11.

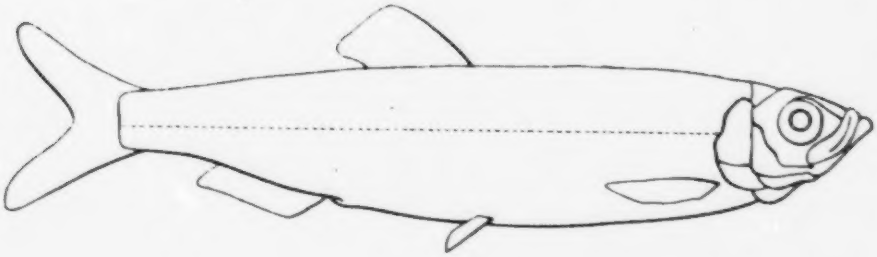


Fig. 12.

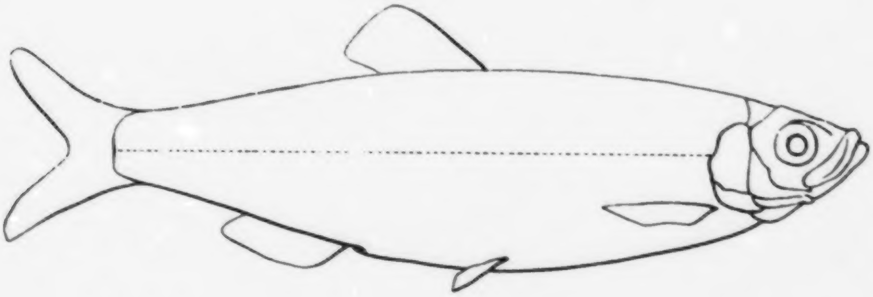


Fig. 13.

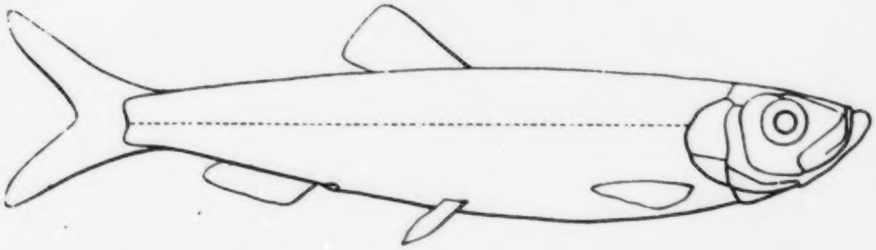
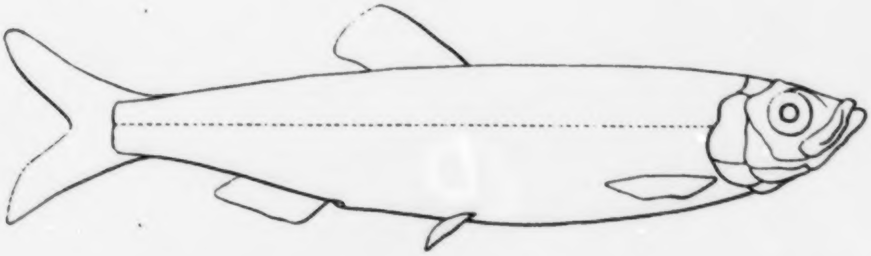
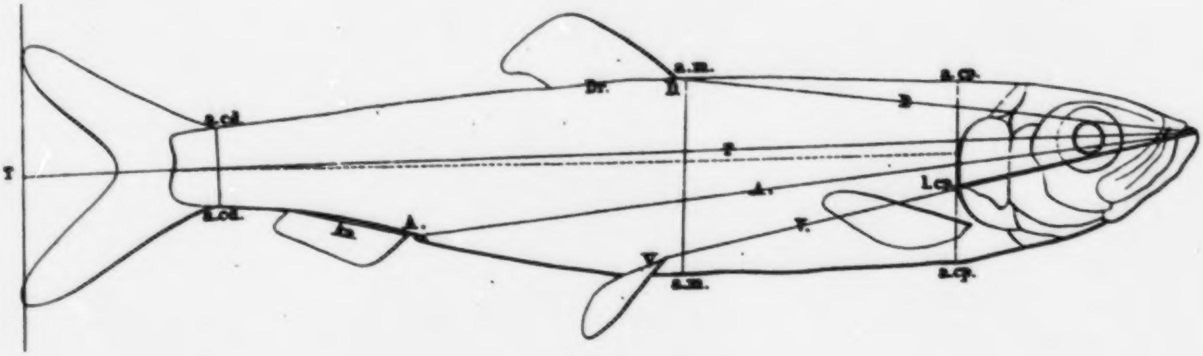


Fig. 14.



Explanatory illustration of formulae



1. Lateral head length. Measured from the tip of the lower jaw with the mouth closed to the hindmost point of the operculum (l. cp.).
The ratio of total length to lateral head length is
6.1: 1 to 5.6: 1 at level d,
5.5 " 5.0 " c,
4.9 " 4.4 " b,
4.3 " 3.8 " a, and
3.7 " 3.2 " 0.

2. Ratio of the length of the base of the dorsal fin to the base of the anal (Drs: An). 1. Drs. < An 2. Drs => An.

3. Maximal body height. Usually between the pectoral fin and the origin of the dorsal (a. m.). The ratio of total length to maximal height is 1000: 238-218 at level 0,
{217-197 " 1,
{196-176 " 2,
{175-155 " 3, and
154-134 " 4.

4. Height at the back of the head (a. cp.). The ratio of total length to the height at the back of the head is 1000:
129-142 at level 0,
{143-156 " a,
{157-170 " b,
{171-184 " c, and
185-198 " d.

5. Height at the origin of the caudal fin (a. cd.). The ratio of total length to the height at the end of the tail is 1000: 37-46 at level -I,
47-56 " 0,

{57-66 " I,
{67-76 " II,
{77-86 " III,
87-96 " IV, and
97-106 " V.

6. Dorsal fin location (D.). Measured by the linear distance from the tip of the lower jaw with the mouth closed to the origin of the dorsal fin. The ratio of total length to this measurement is 1.68-1.77: 1 at level -3,
1.78-1.87 " -2,
1.88-1.97 " -1,
1.98-2.07 " 0,
{2.08-2.17 " 1,
{2.18-2.27 " 2,
{2.28-2.37 " 3, and
2.38-2.47 " 4.

7. Ventral fin location (V.). Measured by the linear distance from the tip of the lower jaw with the mouth closed to the anteriormost point of the base of the ventral fin. The ratio of total length to this measurement is
1.89-1.96: 1 at level 0,
1.97-2.04 " a}
2.05-2.21 " b}
2.13-2.20 " c}
2.21-2.28 " d, and
2.29-2.36 " e.

8. Location of the anus (A.). Measured by the linear distance from the tip of the lower jaw with the mouth closed to the anus. The ratio of total length to this measurement is 1.26-1.30: 1 at level -III,
1.31-1.35 " -II,
1.36-1.40 " -I,
1.41-1.45 " 0,
1.46-1.50 " I}
1.51-1.55 " II}
1.56-1.60 " III}
1.61-1.65 " IV, and
1.66-1.70 " V.

9. Length of the base of the anal fin (An.). The ratio of total length to the length of the base of the anal fin is 1000 to 54-66 at level -A,
67-79 " B,
80-92 " A}
93-105 " B}
106-118 " C},
119-131 " D,
132-144 " E, and
142-157 " F.

10. Number of keel scales between head and ventrals (K_1)
Level 0. 32-31
" {a. 30-29
" {b. 28-27
" {c. 26-25
" d. 24-23
" e. 22-21
" f. 20-19

11. Number of keel scales between ventrals and anus (K_2)
Level -I. 21-20
" 0. 19-18
" { I. 17-16
" { II. 15-14
" {III. 13-12
" IV. 11-10
" V. 9-8

12. Total number of keel scales ($K_1 + K_2$)
Level 0. 49-47
{ α. 46 — 44
{ β. 43 — 41
{ γ. 40 — 38
δ. 37 — 35
ε. 34 — 32

13. Fat content categories:
exceptional
very high
definitely high
high
moderate
low
none

Only fat among the entrails in the body cavity is considered.